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NIGHT SKY RADIOMETRIC MEASUREMENTS DURING FOLLOW-ON-EVALUATION TESTING OF AN/PVS-7 (A, B) AT FORT BENNING, GA

by

Raymond J. Stefanik

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The characterization of the lighting conditions during field testing of night vision intensifier systems requires more information than can be obtained by a photometer. The Follow-on-Evaluation (FOE) testing of AN/PVS-7 Night Vision Goggles at Fort Benning, GA (Oct 86-Dec 86) required a radiometric characterization of the nightime spectral content in the region encompassing that of the generation two and generation three image intensifier photocathodes (400 to 920nm) used in the goggles. A night sky radiometer (NSR) measuring system was designed and fabricated by the Center for Night Vision and Electro-0ptics for the purpose of characterizing the night sky spectral content during the FOE test. This report discusses the design features of the NSR, its measuring techniques, and the results of the night sky conditions during the FOE test at Fort Benning.

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SECTION I. INTRODUCTION

The characterization of the irradiation conditions during field testing of night vision intensifier systems requires more information than can be obtained by a photometer.

> *Confusion and misinterpretation results from the use of photometric units used to characterize the interaction of light with sensors other than the human eye . . . . A method for resolving this confusion and misinterpretation is to abandon the footcandle and to measure the scene illumination in radiometric units (Watts cm^{-2} μm^{-1} not lumen(s) ft^{-2}).*[1]

The realization and understanding that 10^{-4} footcandle of natural night sky irradiation is much different than 10^{-4} footcandle from a tungsten lamp or from a light emitting diode or even from an artificially contaminated night sky are fundamental to assessing image intensifier field test results, and to understanding the need for radiometric measurements.

The Follow-on-Evaluation (FOE) testing (20 October 1986 through 20 December 1986 at Fort Benning, GA) of the Night Vision Goggles AN/PVS-7(A) and the AN/PVS-7(B), comprised of a mix of image intensifiers with generation two (Gen2) and generation three (Gen3) photocathodes, required the radiometric characterization of field irradiation conditions during the test. Since no off-the-shelf radiometric equipment was available to measure the low levels of the night sky spectral irradiance, the Image Intensifier Engineering Team of the Center for Night Vision and Electro-Optics (CNVEO) undertook the task to design and fabricate a Night Sky Radiometer (NSR) for the US Army Infantry Board at Fort Benning during the FOE test.

The design features of the NSR, its measuring technique, and the results of the "illumination" conditions during the FOE test are presented in this report. In presenting the field test results, irradiance levels in terms of "footcandles", "Gen2 normalized irradiance", and "Gen3 normalized irradiance" are utilized. The report defines these units. The derivations of equations used to compute these values from the data measured by the NSR are in the appendices. The algorithm used for computing the "percent artificial light contribution" to the night sky recordings is also in the appendices, along with all spectral irradiance measurement curves (including the numerical data for each curve in a tabular form) and the meteorological conditions during each measurement.

SECTION II. MEASURING TECHNIQUE

The design of any radiometric measuring equipment must consider the various conditions and requirements under which the equipment will be utilized. The primary requirement of the NSR was to characterize the spectral content of the incident field radiation from the night sky in the spectral region encompassing that of the Gen2 and the Gen3 intensifier responses (i.e., 400 to 920 nanometers [nm]), and to determine the presence and amount of artificial light contributions to the night sky spectral content.

To characterize the spectral content of incident field radiation, the geometry of the source(s) irradiating the area must be considered. The most popular tendency is to presume the source to be *Lambertian*, a convenient assumption for simplified analytical purposes, which states that the sky provides equal irradiance from all directions. Unfortunately, in areas near artificial sources (from cities, shopping centers, etc.), the Lambertian assumption is most misleading. For example, the frontal illumination of a target facing the source of artificial light is much different from one facing away from the artificial source. Thus, the measuring technique must consider this factor.

The geometry of the Fort Benning test sites in relation to probable sources of artificial light was a factor also considered in the design of the NSR. With the city of Columbus located 14 miles from the most distant test areas (Griswold Range and Lae Field), it was assumed that the lowest levels of illumination would be approximately an order of magnitude higher than that of natural, clear, starlight illumination.

Another factor considered in the NSR design was the restricted time available to implement the measurement equipment (6 months: April to October 1986). Thus, the design had to maximize the probability of success with little or no time allowed for modification.

There are basically two constraints imposed on the design of an NSR: **sensitivity**, which dictates the lowest measurable power level of radiation; and **spectral bandwidth**, which dictates the minimum resolvable spectral interval of the radiation samples. The natural, clear, moonless night sky exhibits on the order of 1 picowatt per centimeter square per nanometer [$pW/(cm^2nm)$]; thus, for a 10nm spectral measuring bandwidth, $10pW/cm^2$ sensitivity is required by the NSR. Such a sensitivity is marginally achievable by an NSR having a 10nm bandpass filter and a photomultiplier tube as a detector of the power density within the 10nm band. Natural, overcast, starlight conditions or under-canopy measurements would require at least an order of magnitude more sensitivity.

It was considered at the outset that a measurement spectral bandwidth of up to 50nm would provide sufficient information relative to the signal levels available to the Gen2 and Gen3 systems. It is preferable to maximize the bandwidth for low signal acquisition since wider bandwidths intrinsically provide more signal power.

With all factors considered, the NSR was designed as shown schematically in Figure 1. The method was to measure the spectral radiance [pW/cm^{2}nm]) of a flat diffuse surface (a white panel having near 100% reflectance) which is irradiated by the night sky. Thus, the reflected radiation as measured by the NSR equals the incident radiation on the panel. One may consider the panel to be a target irradiated by the night sky, and since it has nearly 100% reflectance, its reflected radiant level equals the incident radiant level on its surface.

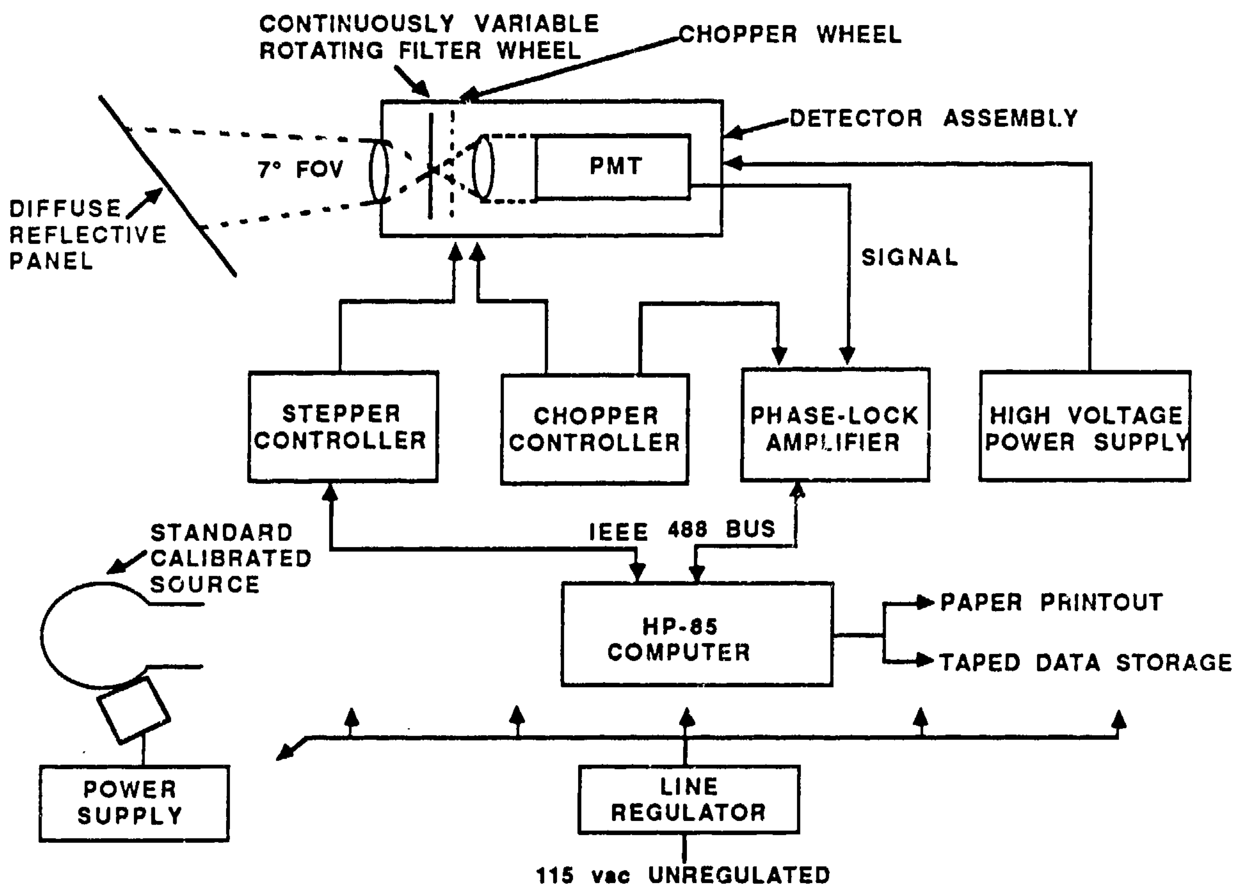


Figure 1. Night Sky Radiometer

The most critical components of the NSR in the detector assembly are the continuously variable rotating **filter wheel** and the **photomultiplifer tube** (PMT). The filter wheel is the optical component which separates the discrete spectral bands of radiation: it acts like a tuneable bandpass filter which passes only the radiation within the spectral interval selected. Tuning the filter wheel is accomplished by rotating the wheel to the selected center passband wavelength.

The PMT component detects the band of radiation passed by the filter, and converts the input flux of radiation to a proportionate output current for the electronic processing equipment. The PMT has a GaAs reflective-mode cathode which exhibits a response in the 400 to 920nm spectral region as required.

Since PMTs generally exhibit a rather variable output dark current due to thermal effects, the incorporation of a chopper wheel with a phase-lock amplifier alleviates the otherwise cumbersome need of dark current (or offset) suppression for each discrete value measured. The theory behind phase-lock signal detection and enhancement is not discussed here as it is widely available in the literature. Basically, the phase-lock method eliminates the electronic offset and noise problems frequently encountered in low-level signal detection equipment where the signal is primarily dc.

The input objective of the detector assembly images the panel onto the filter wheel. The fields lens collects the diverging rays from the filter wheel and collimates the rays to the PMT. The components of the detector assembly are housed in a sealed aluminum case for protection from the environment. Not shown in Figure 1 are a shutter and an eyepiece viewing assembly located between the input objective and the filter wheel of the detector assembly.

The functions of the peripheral electronic equipment are as follows:

Stepper Controller (SC). The SC moves the filter wheel to the selected center wavelength of the filter. With 4,000 steps per revolution, the SC provides sub-nanometer positioning accuracy. The SC steps the filter wheel to the next center wavelength upon command of the computer.

Chopper Controller (CC). The CC rotates the chopper wheel at the selected rate (165 CPS) and provides the reference chop signal to the phase-lock amplifier.

Phase-Lock Amplifier (PLA). The PLA recieves the chopped current signal from the PMT along with the reference chop signal. The PMT current is amplified, demodulated, and digitized for input to the computer after stabilization. Initialization and the sensitivity setting of the PLA are controlled by the computer.

High Voltage Power Supply (HVPS). The HPVS provides the power to the PMT at a nominal (-) 1,000vdc.

Computer. The computer is a Hewlett-Packard Model HP-85 which is the fast-acting "brain" of the operation. The computer first initializes the SC and PLA and then has the PLA search for the required sensitivity setting of the PLA for signal acquisition. Then it acquires the signal from the PLA and applies the calibration factor to the acquired signal level to convert the PMT current to the corresponding unit of irradiance. It stores this measured irradiance level in memory, then instructs the SC to move the next center wavelength continuing with the same sequence for the data acquisition and stoarge for all 53 points ($\Delta\lambda$ = 10nm) measured throughout the 400 to 920nm spectral region. The computer stores the 53 data points on tape for future analysis purposes, and also prints out the spectral irradiance curve along with three computed integrations which yield the three "light level" values: photopic [FC], Gen2 normalized irradiance [HN2] and the Gen3 normalized irradiance [HN3]. (These will be discussed later). All functions the computer performs would make spectral irradiance measurements impractical without the aid of computer control and computerized data analysis.

Line Regulator (LR). The LR smoothes the 110vac, 60 Hz power variations from unregulated sources (such as portable generators), important for computers and computer-controlled equipment to function properly.

Standard Calibrated Source (SCS). The SCS is a light source having a certified calibration of spectral radiant sterance output in the 400 to 1,000nm spectral region. It is used each time the equipment is turned on in order to calibrate the NSR at each of the discrete 53 points of the measurement band. This is necessary since the PMT sensitivity characteristics change with temperature and time.

The methodology of using a white reflective panel for night sky spectral measurements had been utilized by the Night Vision Laboratory in 1968 by Vatsia et. al. [2] The data presented in their report served as a useful guide in the analysis of designing the hardware and software for the NSR. Also, by designing the measurement technique with a similar optics geometry to that of Vatsia, the results from the NSR can be directly compared with the Vatsia measurements. The baseline night sky distribution, used to normalize the computed Gen2 and Gen3 irradiance, is derived from the Vatsia recordings (See Appendix B).

SECTION III. INSTRUMENTATION LAYOUT

The NSR measurement system was housed and transported to the test sites in a mobile van equipped with a 115vac power generator, air conditioning, and heater. At the test site, the NSR detector assembly, reflective panel, and standard calibration source were tripod-mounted and positioned outside the van (Figure 2). A Pritchard photometer Model 1980-A was also positioned next to the NSR detector assembly and used solely to check the result of the computed illuminance for each run of the NSR system. An umbilical cord interconnected the external equipment to the electronic instrumentation and power inside the van (Figure 3). The internal equipment included the computer, stepper controller, chopper controller, phase-lock amplifier, high voltage power supply, line regulator, and the standard source power supply. The NSR's major system components are:

Reflective Panel	LabSphere, >95% reflectance 400 to 1,000nm
Chopper Wheel/Controller	Stanford Research, SR540, 165 Hz
Filter Wheel	OCLI, Model CV400/1200, 400 to 1,200nm (17 to 34nm BW)
Stepper Controller	Parker/Compumotor, Model 3000-1-P-488
Photomultiplier Tube (PMT)	Hamamatsu, GaAs Reflective Mode operated at 1,000v, 400 to 900nm region of response
Phase-Lock Amplifier	Stanford Research, SR530
Computer	Hewlett-Packard, HP-85
Standard Source	Hoffman, Model RS-65/c, calibrated in $\mu W\ CM^{-2}\ SR^{-1}\ nm^{-1}$
High Voltage Power Supply	Fluke, Model 415B, –1,000v
Line Regulator	Sorenson, ACR 2000, 115vac out
Photometer	Pritchard, Model 1908A, 1° FOV
Detector Input Objective	64mm dia, 195mm FL, F3.05
Field Lens	16mm dia, 35mm FL, F2.19

Figure 2. External Equipment Layout (Left to Right: Reflective Panel, Standard Calibration Source, NSR Detector Assembly, Photometer)

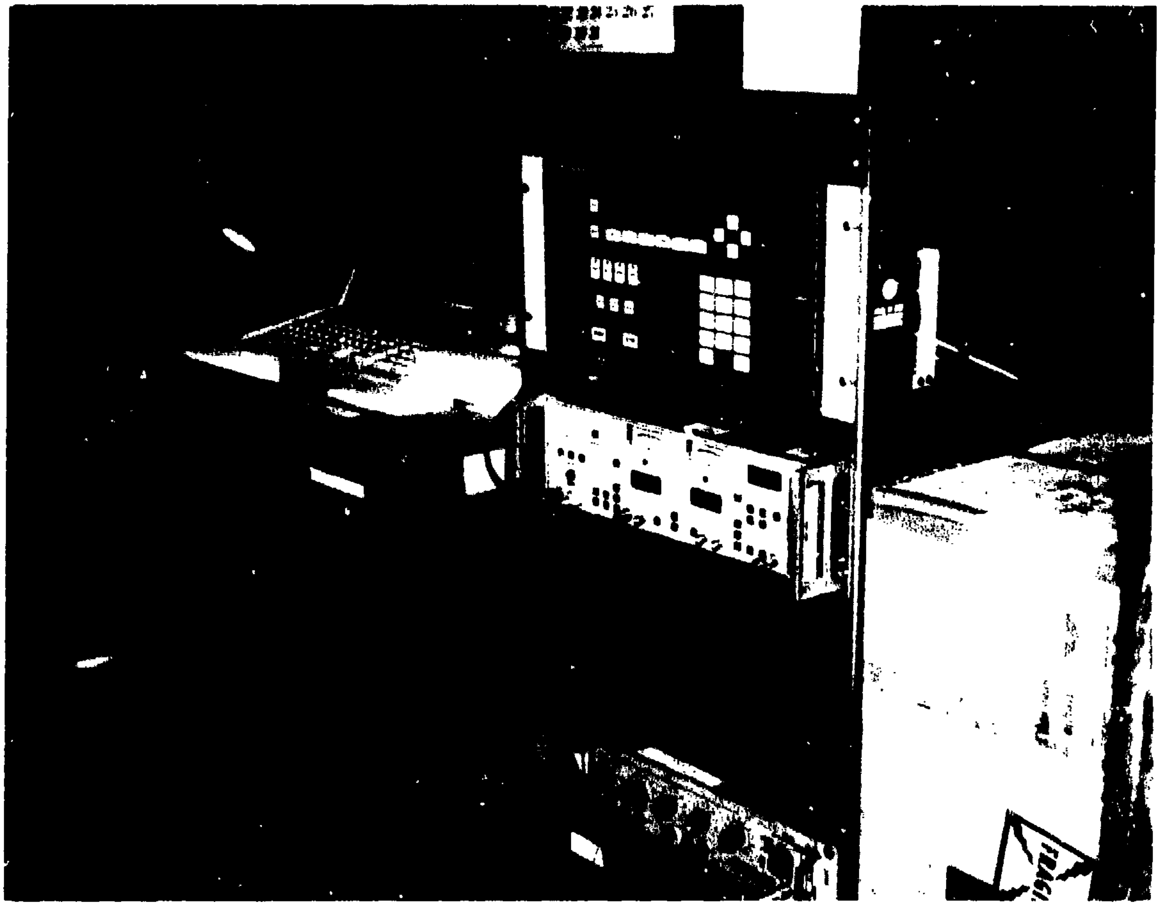


Figure 3. Internal Equipment Layout (Left: Computer; Top to Bottom of Rack: Stepper Controller, Phase-Lock Amplifier, High Voltage Power Supply, Line Regulator)

The reflectance panel was always situated in an open area and oriented in a direction having minimal obstructions toward the horizon. The panel was inclined at a nominal 45 degrees. The detector assembly was aligned with its optical axis intercepting the central area of the panel such that the entire field-of-view (FOV) of the detector (7 degrees) was encompassed by the panel's surface.

All equipment power was then applied and allowed to stabilize for 15 minutes. For the calibration run, the standard source was positioned directly in front of the detector assembly's input optics (Figure 4). At the completion of the scan, the standard source was lowered out of the way in order to present the reflectance panel in view of the NSR detector (Figure 5). The successive scans of the NSR were performed as shown in Figure 5 to acquire the night sky incident radiation data. The computer software was designed to prompt the operator along each step of the setup procedure and data acquisition process. Additional calibration runs were performed each night at the operator's discretion, and each time the panel was oriented in a different direction or location. The measured spectral irradiance data from each run was sequentially stored by the computer onto a digital data tape under a separate file name (FILnnn) for future analysis.

During each night sky measurement, additional data was gathered including date, time, and test site location; reflectance panel azimuth and inclination; moon inclination; moon azimuth and phase; and meteorological information such as cloud cover and altitude (provided on an hourly basis by the local airport), temperature, and relative humidity (wet bulb method).

To prevent external gear damage, and since the panel's reflectance and the optics transmission characteristics would give faulty data if there was any surface moisture, no measurements were attempted during inclement weather conditions.

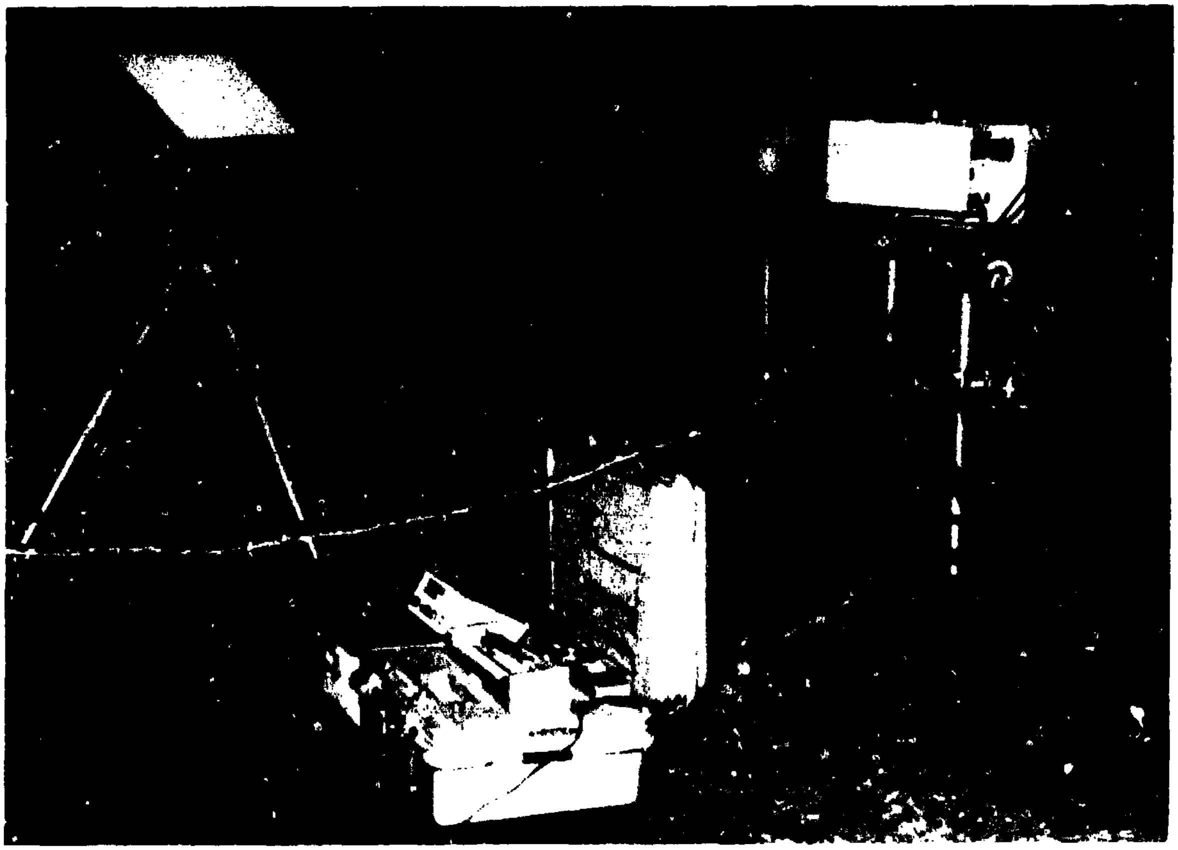


Figure 4. Setup for the Calibration Run

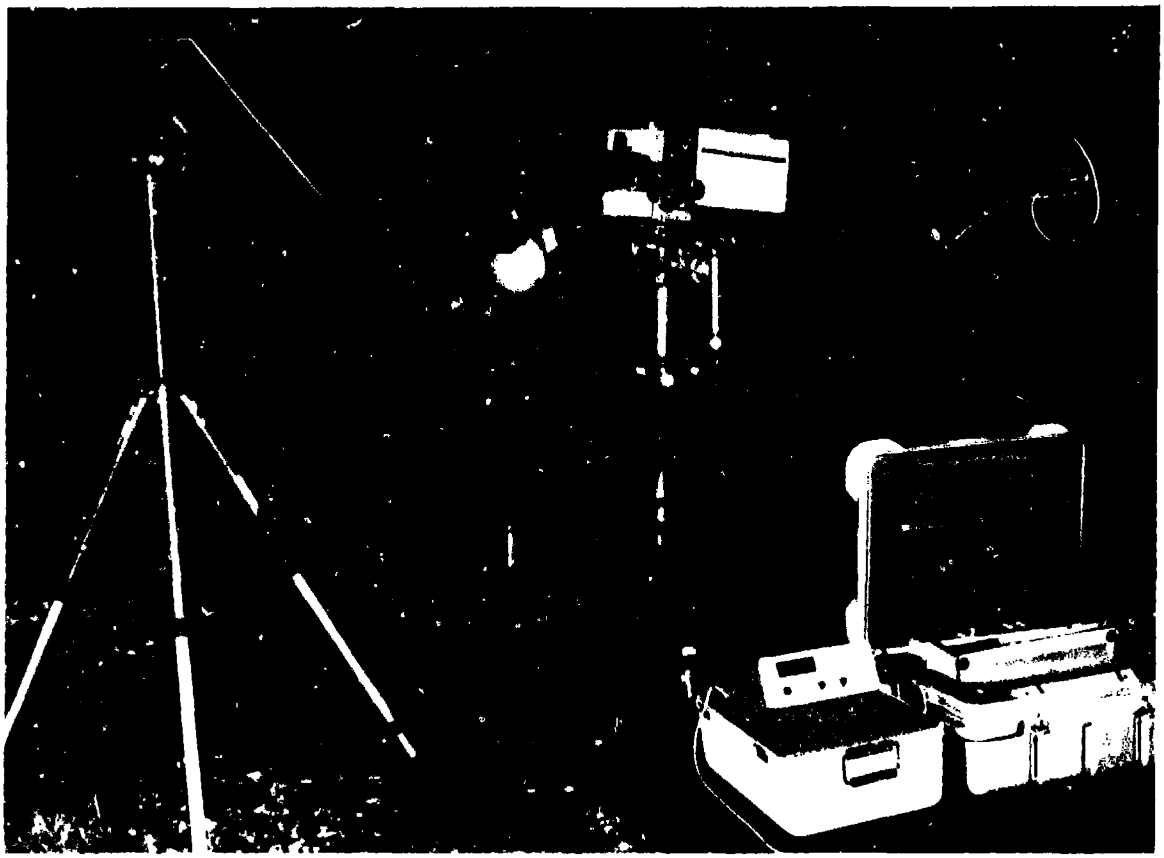


Figure 5. Setup for Acquiring the Night Sky Incident Radiation Data

SECTION IV. SPECTRAL DATA ACQUISITION AND COMPUTATIONS

Data acqusition is accomplished by stepping the filter wheel at 10nm increments starting at 400nm and ending at 920nm. At each wavelength interval, the phase-lock amplifier detects the chopped current signal from the PMT, amplifies, and demodulates the signal to provide a single data value of PMT current $I(\lambda)$ [amps] at that wavelength interval to the computer. The filter wheel then steps to the next wavelength interval to yield a new data value, $I(\lambda + 10\text{nm})$, and continues this process up to the 920nm wavelength, completing one scan of the NSR.

The first scan performed by the NSR is a calibration run, accomplished by placing the standard calibration source in front of the input optics of the detector assembly and having the NSR perform its scan. The data values accrued during this run provide the necessary calibration factors for the subsequent night sky runs as follows:

Let $W_S(\lambda)$ = calibrated standard source irradiance values $\left[\text{pW cm}^{-2}\text{nm}^{-1}\right]$

$I_S(\lambda)$ = corresponding PMT current [amps] provided to the computer

Then, the calibration factor (or transfer function of the NSR), $F(\lambda)$, is computed as follows:

$$F(\lambda) = \frac{I_S(\lambda)}{W_S(\lambda)} \quad \left[\frac{\text{Amps}}{\text{pW cm}^{-2}\text{nm}^{-1}}\right] \qquad \textbf{Equation 1}$$

Thus, 53 calibration factors (constants) are stored in computer memory at the end of the scan: F(400), F(410) . . . (F920).

At the completion of the calibration run, the standard source is removed and the NSR is aligned to look at the white reflective panel which is irradiated by the night sky. The night sky spectral irradiance measurement is now accomplished by having the NSR perform its scan sequence again. Knowing the transfer values of the NSR (the $F(\lambda)$ calibration factors), and the PMT current data values, $I(\lambda)$, the night sky irradiance, $W(\lambda)$, can now be computed as follows:

$$W(\lambda) = \frac{I(\lambda)}{F(\lambda)} \quad \left[\text{pW cm}^{-2}\text{nm}^{-1}\right] \qquad \textbf{Equation 2}$$

Thus, at the completion of the scan, the $W(\lambda)$ function is stored in computer memory with 53 discrete spectral points from $\lambda = 400$ to 920nm, $\Delta \lambda = 10$nm. The $W(\lambda)$ array is then recorded onto a digital tape by the computer for futue analysis.

The acquisition of the night sky specrtral irradiance function, $W(\lambda)$, now provides the basic information necessary to compute the quantified night sky irradiance integrals: illuminance, Gen2 normalized irradiance, and Gen3 normalized irradiance.

In order to compare the effect of various irradiance conditions—different spectral distributions—on the response of a second or third generation intensifier, a normalized Gen2 [HN2] and a normalized Gen3 [HN3] irradiance are introduced. The normalized irradiances are a measure of the incident radiation in the passband of the second and third generation intensifiers. They are normalized such that the photopic illuminance [fc], the normalized Gen2 irradiance [HN2], and the normalized Gen3 irradiance [HN3] all have the same numerical value for a natural moonless night sky. The natural moonless night sky spectral distribution is defined by the average of the Vatsia et. al. data.[2] (See Appendix B, Figure B-1.) A detailed mathematical derivation and description of the normalized irradiances are in Appendices A through E.

The usefulness of the normalized Gen2 and Gen3 irradiances may be described as follows:

- If the incident moonless night sky irradiation were natural (i.e., no artificial light), then the numeric value of HN2 would equal that of HN3, but the higher sensitivity of the Gen3 intensifier would result in higher signal current (i.e., better performance) than that of the Gen2 intensifier.

- If the night sky irradiance were artificially contaminated with photopic efficient light (i.e., more power in the shorter wavelength region), then HN2 would be greater than HN3. This would imply that the signal current in the Gen2 intensifier would be closer to the Gen3 intensifier signal current yielding a smaller performance difference than with the above condition. (See "Parameters Affecting Imaging Intensifier Performance" in Pollehn's report.[1])

The values of fc, HN2, and HN3 are computed from the night sky spectral irradiance, $W(\lambda)$, as follows:

Let E = illuminance [fc]

θ_{2N} = Gen2 normalized irradiance [HN2]

θ_{3N} = Gen3 normalized irradiance [HN3]

Then, $E = 9.29 \times 10^{-10} \int K(\lambda)W(\lambda)d\lambda$ [fc] **Equation 3**

$\theta_{2N} = 9.29 \times 10^{-10} \int R_{2N}(\lambda)W(\lambda)d\lambda$ [HN2] **Equation 4**

$\theta_{3N} = 9.29 \times 10^{-10} \int R_{3N}(\lambda)W(\lambda)d\lambda$ [HN3] **Equation 5**

Where the spectral weighting functions are:

$K(\lambda)$ = the photopic luminosity function, [L/W] vs λ (See Figure A-1)

$R_{2N}(\lambda)$ = the normalized responsivity of a Gen2 cathode, [L2/W] vs λ (See Figure D-1)

$R_{3N}(\lambda)$ = the normalized responsivity of a Gen3 cathode, [L3/W] vs λ (See Figure E-1)

The computer software performs the three integrations using *Simpson's Rule* for numerical integration:

$$\int y(\lambda)d\lambda = \frac{10}{3} \sum_{n=1}^{53} a \cdot y(390 + 10n) \qquad \textbf{Equation 6}$$

where a = 1, 4, 2, . . . 4, 2, 4, 1

Having the three quantified night sky integrals (E, θ_{2N}, θ_{3N}), one last set of computations may now be performed—the percent artificial light contribution in the night sky. However, this can only be accomplished on moonless nights since the moon's contribution itself could not be determined. (See Appendix F.) The percent artificial contribution (P_A) is computed as follows:

For the photopic spectral band: $$P_A = \frac{E - 7.39 \times 10^{-5}}{E} \times 100\% \qquad \textbf{Equation 7}$$

For the Gen2 spectral band: $$P_A = \frac{\theta_{2N} - 7.39 \times 10^{-5}}{\theta_{2N}} \times 100\% \qquad \textbf{Equation 8}$$

For the Gen3 spectral band: $$P_A = \frac{\theta_{3N} - 7.39 \times 10^{-5}}{\theta_{3N}} \times 100\% \qquad \textbf{Equation 9}$$

The establishment of the Gen2 and Gen3 normalized spectral weighting functions, $R_{2N}(\lambda)$ and $R_{3N}(\lambda)$, and the percent artificial computations are derived from the baseline night sky spectral distribution, $W_B(\lambda)$. (See Appendix B.) If any night sky measurement duplicated that of the baseline, the following results would have been obtained:

with $W(\lambda) = W_B(\lambda)$

then $E = 7.39 \times 10^{-5}$fc

$\theta_{2N} = 7.39 \times 10^{-5}$HN2

$\theta_{3N} = 7.39 \times 10^{-5}$HN3

and $P_A = 0\%$ for all spectral bands.

SECTION V. RESULTS—NIGHT SKY SPECTRAL IRRADIANCE

Of the 57 spectral irradiance scans recorded by the NSR during the FOE test, 32 scans of night sky irradiance (see Appendix H) were measured at three test sites:

- Griswold (4 test weeks), 21 scans
- Lae Field (1 test week), 6 scans
- Simpson Range (1 test week), 5 scans.

The highest set of light level recordings were at Lae Field (10-12 November 1986), 14 miles south of Columbus, GA. The high levels were attributed to the presence of the moon (67% to 84%) on all nights. The light levels at this site were greater than 10^{-3} fc or HN2 or HN3. Scattered or overcast cloud conditions were present each night at this site. The presence of artificial light contribution was noticeable in the recordings but negligible because of the much higher contribution of the moon itself. The differences between Gen2 and the Gen3 light levels (HN2 and HN3) at such high light levels as these would not skew the FOE test results in favor of either technology. This is because both system types (Gen2 and Gen3) were operating in a high light environment, primarily moonlight, and thus were in a hight-light-limiting resolution mode where performance differences are not expected to be dependent on the technology type.

The next hightest set of light level recordings was at the Simpson Range, adjacent to Fort Benning proper. Although the night sky was clear and moonless, the majority of the irradiation at this site (greater than 90%) originated from the nearby street lights, traffic, and Fort Benning's lights in general. The light levels at the target area of this site were nominally 1.3×10^{-3} fc, 9.2×10^{-4} HN2, and 6.9×10^{-4} HN3. These light levels were representative of greater than one-half moon irradiation. Moreover, HN2 is a significant factor of 1.3 times greater than HN3. This indicates that the incident power level in the Gen2 spectral band was 30% greater than in the Gen3 spectral band, compared to a natural starlight-only condition. Thus, the nearby presence of the artificial lights provided 30% more signal power to the Gen2 systems than to Gen3, which may be of significance in comparing the FOE test results of Gen2 vs. Gen3. The test results may have been skewed to favor Gen2 with up to 30% more signal power than would have existed under natural conditions.

It is critical to understand that having more power in the Gen2 spectral band than in the Gen3 spectral band (i.e., HN2 > HN3), **does not** imply that a Gen2 system would have the better performance. In fact, it is expected that the HN2 value would have to exceed nearly **two times** (i.e., 100% greater than) the HN3 value before the Gen2 system performance would equal that of the Gen3 system.

The majority of night sky recordings were gathered at the Griswold area, 13 miles south of Columbus, GA. The light levels at this site ranged photopically from 1.3×10^{-4} fc from the south, up to 3×10^{-3} fc during a moonlit condition. The highest levels recorded were during moonlit conditions (greather than 80% moon) during the first week of the FOE (21 October 1986 and early morning of 23 October 1986). The light levels on these two nights nominally ranged from 1.5×10^{-3} to 3×10^{-3} with insignificant differences between the Gen2 and Gen3 spectral bands (HN2 and HN3). Any contribution of artificial lights during these two nights were negligible as the moon was the greater source of irradiation. FOE test results during these nights may be considered representative of natural moonlight conditions.

The moonless periods at Griswold showed a very wide range of irradiation dependent primarily on meteorological conditions and on the direction of the irradiance measurements. The lowest set of recordings were during the last week of the FOE (the nights of 2 and 3 December 1986), but only when no clouds were present. During the clear, low humidity periods that occurred that week, the lowest light level recorded was 8.6×10^{-5} HN3 from the south. The highest light level was 1.8×10^{-4} HN2 from the north. These levels corresponded to 1.2 to 2.4 times greater than a natural, clear starlight level of irradiation. The presence of artificial light contamination due to atmospheric scattering from the city of Columbus was obvious from the spectral recordings (see FIL053 through FIL057, Appendix H), and was the primary reason for these higher levels. The estimated amounts of scattered artificial light can be computed as follows:

Photopic Band $\left\{\begin{array}{l}\text{Min } 1.3 \times 10^{-4} - 7.4 \times 10^{-5} = 5.6 \times 10^{-5}\text{ fc} \\ \text{Max } 2.5 \times 10^{-4} - 7.4 \times 10^{-5} = 1.8 \times 10^{-4}\text{ fc}\end{array}\right\}$ 1.2×10^{-4} fc Avg. Artificial

Gen2 Band $\left\{\begin{array}{l}\text{Min } 1.1 \times 10^{-4} - 7.4 \times 10^{-5} = 3.6 \times 10^{-5}\text{ HN2} \\ \text{Max } 1.8 \times 10^{-4} - 7.4 \times 10^{-5} = 1.1 \times 10^{-4}\text{ HN2}\end{array}\right\}$ 7.3×10^{-5} HN2 Avg. Artificial

Gen3 Band $\left\{\begin{array}{l}\text{Min } 8.6 \times 10^{-5} - 7.4 \times 10^{-5} = 1.2 \times 10^{-5}\text{ HN3} \\ \text{Max } 1.4 \times 10^{-4} - 7.4 \times 10^{-5} = 6.6 \times 10^{-5}\text{ HN3}\end{array}\right\}$ 3.9×10^{-5} HN3 Avg. Artificial

The average amount of artificial photopic scattering (1.2×10^{-4} fc) was in very close agreement with an independent analysis of Pollehn[1] who determined the artificial scattering at another test site to be 1.0×10^{-4} fc. Based on averages, only clear starlight and low humidity conditions at the Griswold Test Site presented the closest spectral match to that of natural, clear starlight irradiation. However, the amount of scattered artificial light at Griswold under this condition imposed two effects on the nature of the irradiation:

- The overall amplitude of the incident radiation was higher than would have been present without artificial lights. This added contamination effectively perturbed the night sky irradiance, yielding a photopic average level of 1.9×10^{-4} fc, a Gen2 average level of 1.5×10^{-4} HN2, and a Gen3 average level of 1.1×10^{-4} HN3. It was expected that no artificial contamination would have yielded a light level of 7.4×10^{-5} fc, or HN2 or HN3.

- This perturbation effectively enhanced the Gen2 system's performance more so than that of the Gen3 system. The available Gen2 power level was 2.0 times that of a natural condition

  $$\left(= \frac{1.5 \times 10^{-4}\text{ HN2}}{7.39 \times 10^{-5}} \right).$$

  The available Gen3 power level was 1.5 times that of a natural condition

  $$\left(= \frac{1.1 \times 10^{-4}\text{ HN3}}{7.39 \times 10^{-5}} \right).$$

All other moonless periods at Griswold (FIL006, FIL013, FIL014, FIL023 through FIL028, FIL051, and FIL052, Appendix H) were under conditions of haze or cloud cover. As may be expected, the presence of clouds and the artificial lights in the Columbus area induced a signficant increase of irradiance at the Griswold area. The increase ranged from a factor of 2.6 to 16.2 in the photopic band, 2.2 to 11.6 in the Gen2 band, and 2.2 to 10.8 in the Gen3 band (as compared to a natural, clear starlight condition). This artificially induced increase of radiation again yielded a twofold effect:

- The overall amplitude of the incident radiation was higher than would have been present under natural cloud cover conditions (expected natural conditions would have yielded lower light levels by a factor of 0.04 to 0.25). The actual light level amplitudes measured during these conditions were representative of levels ranging from two times that of natural, clear starlight up to a 1/4 moonlight level.

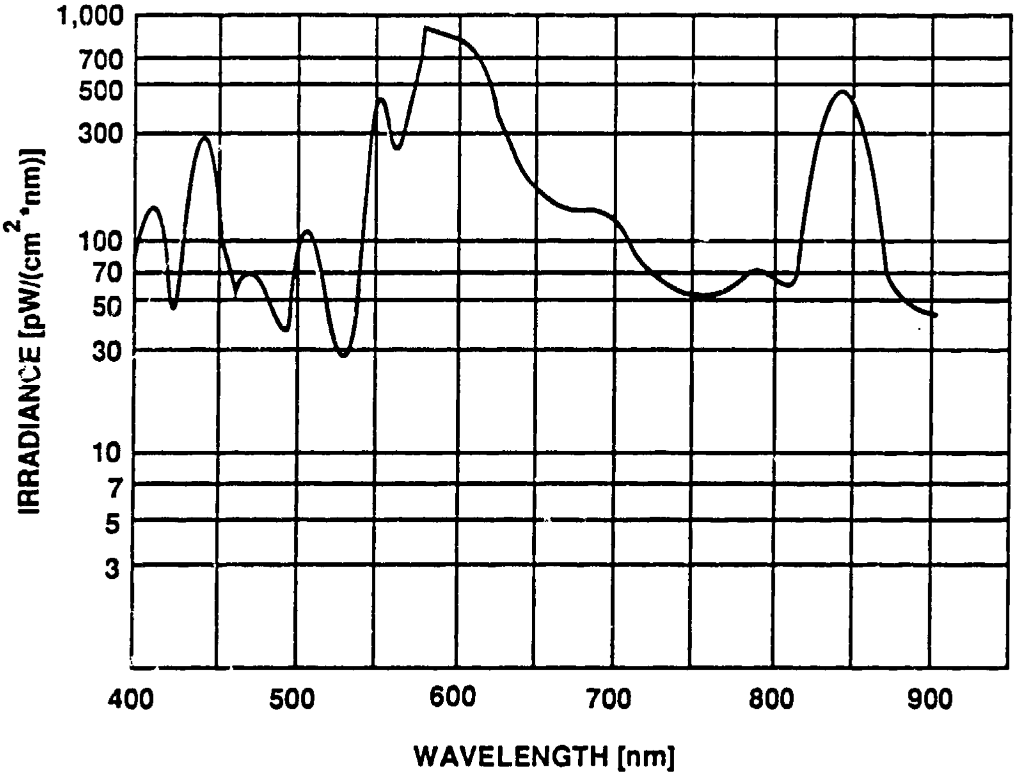
- The perturbation of incident radiation effectively enhanced the Gen2 system performance more so than that of a Gen3 system. The range of enhancement—as compared to a natural, clear condition—was as follows:

	Minimum	Maximum	Average of 11 Files
Gen2	2.2	11.6	5.5
Gen3	2.2	10.8	5.2

SECTION VI. RESULTS—HORIZON/CLOUD MEASUREMENTS AND LAMP MEASUREMENTS

During the first week of FOE testing (22 October 1986), the first noticeable presence of artificial contamination at the Griswold Test Site was recorded (FIL006). In order to ascertain the source and its spectral nature, two recordings were obtained by aiming the NSR detector assembly at the horizon over the city of Columbus (FIL008 and FIL009, Appendix I). One other recording was obtained (FIL015, Appendix I) on another night when a cloud well above the horizon toward Columbus appeared to be the primary reflector of the artificial light. A comparison of these three spectral irradiance plots shows a very close correlation with all night sky spectral irradiance plots recorded during moonless conditions. These recordings were obtained solely for analytical purposes, and not to establish irradiation conditions during FOE test.

It was anticipated that photopically efficient lighting (mercury and sodium) in the urban areas would have been the primary contributor to the artificial contamination. In order to test this assumption, five spectral recordings of high-pressure sodium and mercury lights were obtained (FIL031 through FIL035, Appendix J). The measurements were performed by aiming the NSR detector assembly at the street lights and greatly reducing the sensitivity settings of the equipment. A computer analysis was done combining two of the recordings (a high-pressure sodium and a high-pressure mercury lamp) to obtain a spectral shape that might match the shape of the night sky recordings having the artificial contamination. The plot in Figure 6 is the result of this computer analysis which represents the combined spectral shape of the two lamp types. A comparison of this plot with the night sky recordings shows a close correlation of the spectral shape, indicating that mercury and sodium lights in the area were primary contributors to the artificial contamination at the test sites.



WAVELENGTH [nm]	SPECTRAL IRRADIANCE [pw/(cm^2 nm)]	WAVELENGTH [nm]	SPECTRAL IRRAD. [pw/(cm^2 nm)]
400	101.21	650	164.64
	128.37		141.65
	46.74		129.24
	128.92		130.70
	282.41		129.56
450	106.40	700	111.08
	55.39		87.42
	68.12		68.11
	52.10		59.40
	38.15		54.43
500	101.12	750	51.97
	90.71		52.67
	40.58		55.65
	29.75		64.42
	110.45		67.58
550	423.89	800	63.41
	250.31		60.13
	418.91		117.88
	955.48		307.52
	889.40		456.09
600	826.93	850	363.63
	711.30		153.98
	472.53		65.64
	285.66		49.63
	194.75		44.07
		900	42.35
			0.00
			0.00

Figure 6. HP Sodium + Mercury Lamps

REFERENCES

1. H. Pollehn, *Analysis of Field Tests Comparing Second and Third Generation Image Intensifiers*, US Army Communications-Electronics Command, Center for Night Vision Electro-Optics, July 1986.

2. M. Vatsia, K. Stitch, and D. Dunlap, *Night Sky Radiant Sterance from 450 to 2000 Nanometers, Research and Development Technical Report ECOM-7022*, US Army Electronics Command, Night Vision Laboratory, September 1972.

3. RCA, *Electro-Optics Handbook*, 1968.

SYMBOLOGY

Brackets [ ] enclose the units of measure

CONSTANTS

c	$= 3 \times 10^{8}$ [m/sec]	Speed of light
C_2	$= 4.06 \left[\dfrac{HN2 \times ft^2}{mA}\right]$	Gen2 normalization factor
C_3	$= 1.38 \left[\dfrac{HN3 \times ft^2}{mA}\right]$	Gen3 normalization factor
E_B	$= 7.39 \times 10^{-5}$ [fc]	Luminous flux density of $W_B(\lambda)$
h	$= 6.626 \times 10^{-34}$ [J x Sec]	Planck's constant
H_N	$= 7.39 \times 10^{-5}$ [fc] or [HN2] or [HN3]	Natural contribution to H_T
θ_{B2}	$= 1.82 \times 10^{-5} \left[mA/ft^2\right]$	Gen2 output response of $R_2(\lambda)$ to $W_B(\lambda)$
θ_{B3}	$= 5.35 \times 10^{-5} \left[mA/ft^2\right]$	Gen3 output response of $R_3(\lambda)$ to $W_B(\lambda)$
π	$= 3.14159$	Pi

REFERENCE FUNCTIONS

$K(\lambda)$	[L/W] vs λ	Photopic luminosity function
$R_2(\lambda)$	[mA/W] vs λ	Gen2 absolute responsivity function
$R_{2N}(\lambda)$	[L2/W] vs λ	Gen2 normalized responsivity function
$R_3(\lambda)$	[mA/W] vs λ	Gen3 absolute responsivity function
$R_{3N}(\lambda)$	[L3/W] vs λ	Gen3 normalized responsivity function

$W_B(\lambda)$ $\left[pW \times cm^{-2} \times nm^{-1} \right]$ vs λ — Baseline night sky spectral irradiance distribution

$W_s(\lambda)$ $\left[pW \times cm^{-2} \times nm^{-1} \right]$ vs λ — Standard source calibration values

VARIABLES

E	Luminous flux density [fc] or $\left[L/ft^2 \right]$
$F(\lambda)$	Calibration transfer function of night sky radiometer $\left[amps \times pW^{-1} \times cm^2 \times nm \right]$
H_A	Artificial contribution to H_T [fc] or [HN2] or [HN3]
H_T	Total integrated irradiance [fc] or [HN2] or [HN3]
$I(\lambda)$	PMT signal current [amps]
$I_s(\lambda)$	PMT signal [amps] induced by $W_s(\lambda)$
P_A	Percent artificial contribution to H_T [percent]
$W(\lambda)$	Measured spectral irradiance distribution $\left[pW \times cm^{-2} \times nm^{-1} \right]$
θ_{2N}	Normalized Gen2 response of $R_{2N}(\lambda)$ to $W(\lambda)$ [HN2]
θ_{3N}	Normalized Gen3 response of $R_{3N}(\lambda)$ to $W(\lambda)$ [HN3]
λ	Wavelength [nm]

UNITS OF MEASURE

vac	Volts alternating current
cm	Centimeter
CPS	Cycles per second
vdc	Volts direct current
fc	Footcandle

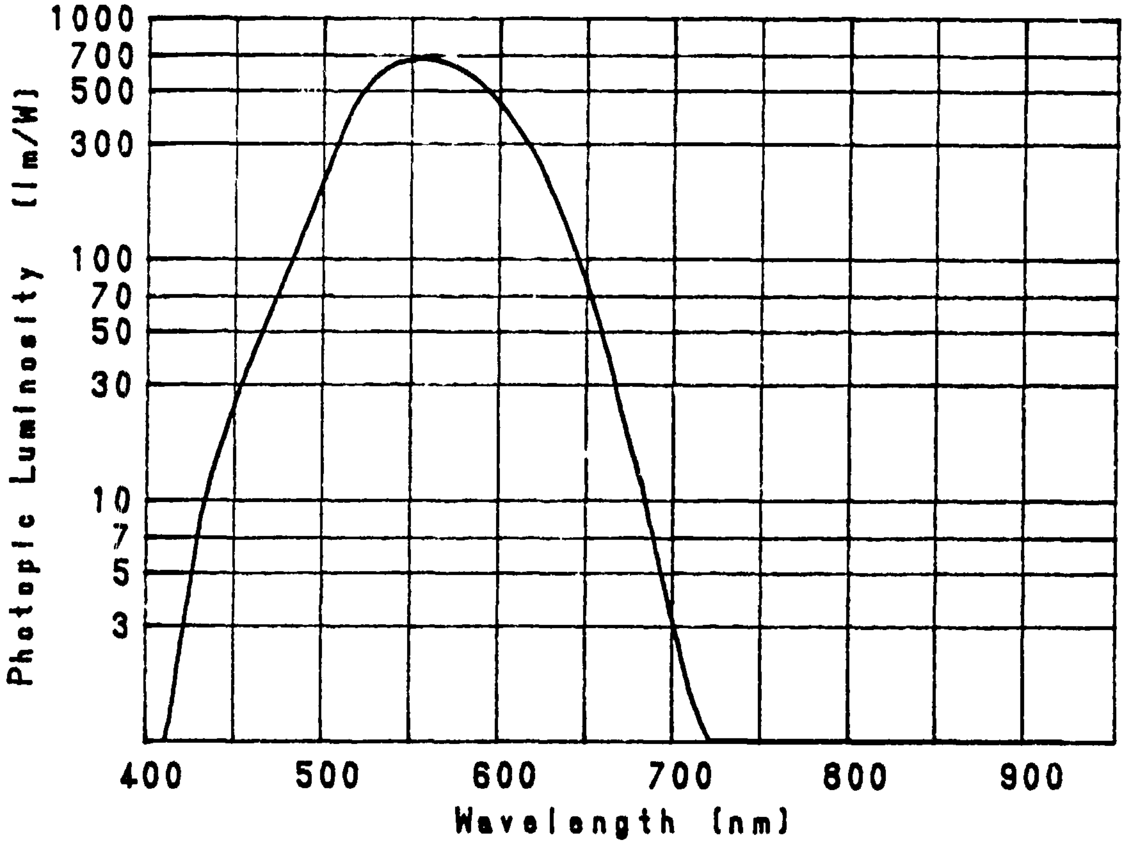
ft	Foot
HN2	Gen2 normalized irradiance
HN3	Gen3 normalized irradiance
Hz	Hertz
J	Joule
K	Degrees kelvin
L	Lumen
L2	Normalized Gen2 response units - luminosity 2
L3	Normalized Gen3 response units - luminosity 3
mA	Milliampere
mm	Millimeter
nm	Nanometer
pW	Picowatt
sec	Second
sr	Steradian
V	Volt
W	Watt
μA	Microampere
μW	Microwatt

APPENDIX A
PHOTOPIC LUMINOSITY FUNCTION, K(λ), ABSOLUTE GEN2 TYPICAL RESPONSE FUNCTION, R2(λ), AND ABSOLUTE GEN3 TYPICAL RESPONSE FUNCTION, R3(λ)

The absolute spectral power distribution $\left[W\ cm^{-2}\ nm^{-1}\right]$ vs λ is most descriptive of incident radiation as it provides sufficient information about the incident power level throughout the wavelength region of interest. Unfortunately, because of the lack of a commercially available field quality measuring device with the sensitivity necessary to quantify the low incremental spectral power distribution of the night sky, it has become more practical and common to quantify the incident radiation of the night sky with a device that measures the integrated product of the spectral power distribution with a standard transfer function. One standard transfer function that has gained wide acceptance and standardization (CIE, 1970) is the photopic luminosity function of the human eye, K(λ) (Fig. A-1). Such a function describes the relative power sensing ability of the eye, and when its product with a spectral power distribution is integrated, the result describes the relative brightness of the spectral distribution as perceived by the eye. The photometer is the instrument that can directly measure this integrated quantity. The photometer's transfer function is generally a close match to that of the photopic luminosity function of the eye, which is expressed in terms of lumens per watt vs wavelength. The integrated quantity measured by the photometer is commonly expressed in terms of lumens per square-foot (or footcandles). Since the transfer function applies spectral weighting to the incident radiation power distribution, the integrated quantity measured by the photometer gives no information about the incident radiation power level nor distribution, but only the "brightness" as perceived by the eye.

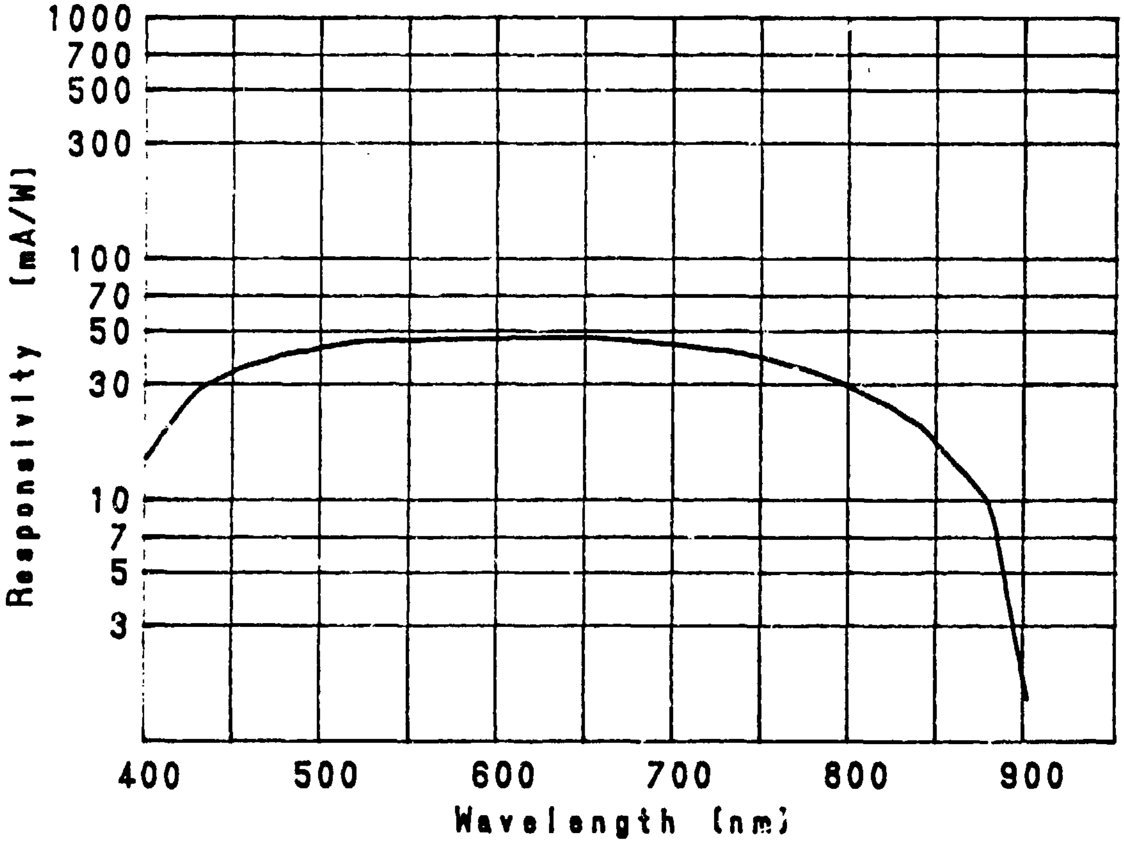
Any nonphotopic detector (such as a generation two or generation three photocathode) perceives the incident radiation with a transfer function of its own, and much unlike that of the eye. The absolute power sensing ability (responsivity) of a typical Gen2 and a Gen3 cathode (Fig. A-2 and A-3 respectively) are expressed in terms of milliamps emitted from the cathode per watt incident vs wavelength, [mA/W] vs λ. The responsivity curves depicted in the figures are that of a typical Gen2 and Gen3 cathode having a sensitivity response to a 2856K distribution of radiation of 350 μA/L and 1300 μA/L respectively. The sensitivity of Gen2 cathodes in general could vary from 240 μA/L to 500 μA/L, whereas the sensitivity of Gen3 cathodes in general could vary from 800 μA/L to 1600 μA/L. Also, the shape of the responsivity curve of the Gen2 and Gen3 cathodes in general vary by some amount, just as the shape of the eye curve varies from one individual to another. The curves chosen for the Gen2 and the Gen3 responsivity, however, are that of typical cathodes presently manufactured.

An absolute transfer function as presented for a Gen2 and a Gen3 cathode will describe the output process of the cathode, when exposed to an incident spectral power distribution of radiation, in terms of milliamps per unit area (the result of integrating the product of the transfer function with the incident spectral power distribution). These absolute transfer functions of the Gen2 and Gen3 cathodes will be applied in later appendixes to describe the incident night sky radiation in normalized terms with that of the corresponding photopic description.



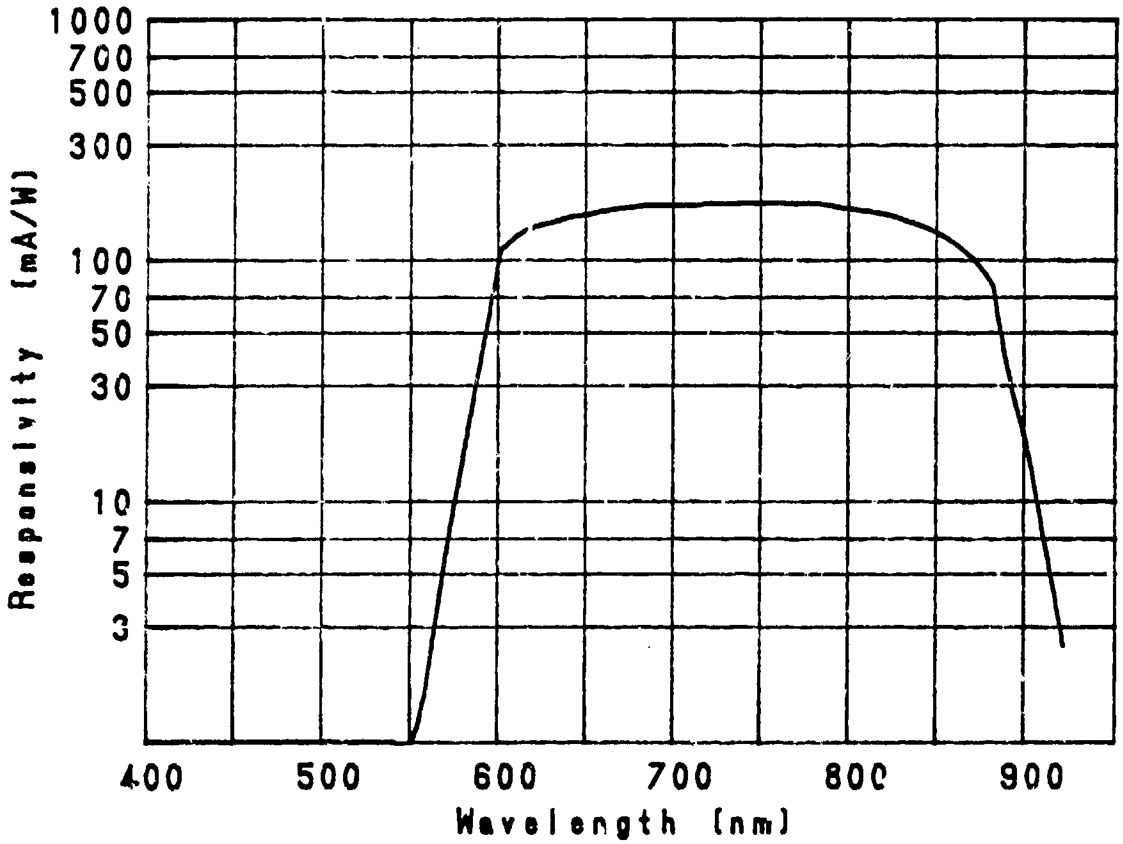
WAVELENGTH [nm]	LUMINOSITY [lm/W]	WAVELENGTH [nm]	LUMINOSITY [lm/W]
400	0.27	650	72.76
	0.82		41.48
	2.72		21.76
	7.89		11.56
	15.64		5.58
450	25.84	700	2.79
	40.80		1.43
	61.88		0.71
	94.52		0.35
	141.44		0.17
500	219.64	750	0.08
	342.04		0.04
	482.80		0.02
	586.16		0.00
	648.72		0.00
550	676.60	800	0.00
	676.60		0.00
	647.36		0.00
	591.60		0.00
	514.76		0.00
600	429.08	850	0.00
	342.04		0.00
	259.08		0.00
	180.20		0.00
	119.00		0.00
		900	0.00
			0.00
			0.00

Figure A-1. Photopic Eye Response, K (λ)



WAVELENGTH [nm]	RESPONSIVITY [mA/W]	WAVELENGTH [nm]	RESPONSIVITY [mA/W]
400	14.80	650	46.70
	18.80		46.50
	23.50		45.90
	28.50		45.30
	31.20		44.60
450	34.00	700	43.80
	36.40		42.80
	38.10		41.80
	40.30		41.10
	41.10		39.90
500	43.00	750	38.50
	43.70		36.70
	45.00		35.20
	45.30		33.20
	45.80		31.10
550	45.90	800	28.90
	46.10		26.60
	46.20		24.60
	46.50		22.10
	46.50		19.60
600	46.50	850	16.40
	46.70		13.70
	46.90		11.30
	46.90		8.60
	46.80		3.50
		900	1.50
			0.00
			0.00

Figure A-2. Gen2 Absolute Response, $R_2(\lambda)$



WAVELENGTH [nm]	RESPONSIVITY [mA/W]	WAVELENGTH [nm]	RESPONSIVITY [mA/W]
400	0.00	650	156.00
	0.00		161.00
	0.00		165.00
	0.00		168.00
	0.00		169.00
450	0.00	700	170.00
	0.00		170.00
	0.00		172.00
	0.00		172.00
	0.00		173.00
500	0.00	750	173.00
	0.00		173.00
	0.00		172.00
	0.00		172.00
	0.00		167.00
550	0.00	800	163.00
	2.10		159.00
	6.50		154.00
	17.20		146.00
	45.20		138.00
600	110.00	850	127.00
	128.00		114.00
	139.00		98.10
	145.00		77.50
	152.00		31.00
		900	15.90
			6.50
			2.50

Figure A-3. Gen3 Absolute Response, R_3 (λ)

APPENDIX B
BASELINE NIGHT SKY DISTRIBUTION, $W_B(\lambda)$

For the purpose of calculating the Gen2 and Gen3 normalized irradiance (HN2 and HN3 respectively), a standard night sky distribution is necessary on which to base the normalized quantities. (See appendixes D and E.) The chosen baseline is the uncontaminated, natural, moonless, clear starlit night sky. The spectral irradiance of the baseline, $W_B(\lambda)$, is given in Fig. B-1 and originates from the data gathered by the Night Vision Laboratory in the late 1960's by Vatsia, et al.[2] This particular set of data was chosen for two reasons: (1) The technique of a diffuse, white, reflective panel and geometry of their measurement setup closely matched the measuring technique of the Night Sky Radiometer; and (2) the data was gathered 18 years ago during a time in which the use of photopic efficient lighting (mercury and sodium lights) was not so widespread as now, thus providing data with minimal artificial contamination in the night sky recordings.

The following three recordings (Fig. B-2) of Vatsia which meet the criteria for the baseline (clear starlight-only) were extracted from the report:[2]

	Date	Time	Location	Referenced Report Page
1.	26 Mar 68	2000	Cooper's Lake, Nashville, NC	14
2.	26 Mar 68	0323	Cooper's Lake, Nashville, NC	14
3.	16 Oct 68	2030	Lake Montauban, Canada	23

The night sky baseline (Fig. B-1) is the average of these three recordings, and with a conversion factor of $\pi \times 10^{11}$ to change Vatsia's measured units of radiant sterance, $L\left[\mathrm{W\ cm^{-2}\ sr^{-1}\ 10\ nm^{-1}}\right]$ to spectral irradiance, $W\left[\mathrm{pW\ cm^{-2}\ nm^{-1}}\right]$ as follows:

$$L\left[\frac{\mathrm{W}}{\mathrm{cm^2\ sr\ 10\ nm}}\right] \times \pi\ \mathrm{sr} \times \frac{10^{12}\mathrm{pW}}{\mathrm{W}} \times \frac{10\ \mathrm{nm}}{10\ \mathrm{nm}} = W\left[\frac{\mathrm{pW}}{\mathrm{cm^2\ nm}}\right] \qquad \text{(B-1)}$$

$$\text{therefore, } L \times \pi \times 10^{11} = W \qquad \text{(B-2)}$$

The photopic incident light level [FC], the Gen2 output response $\left[mA/ft^2\right]$, and the Gen3 output response $\left[mA/ft^2\right]$ of the baseline night sky, $W_B(\lambda)$ (Fig. B-1), can be calculated as follows:

$$E_B[FC] = 9.29 \times 10^{-10} \int K(\lambda)\, W_B(\lambda)d\lambda = 7.39 \times 10^{-5}[FC] \qquad \text{(B-3)}$$

$$\theta_{B2}\left[mA/ft^2\right] = 9.29 \times 10^{-10} \int R_2(\lambda)\, W_B(\lambda)d\lambda = 1.82 \times 10^{-5}\left[mA/ft^2\right] \qquad \text{(B-4)}$$

$$\theta_{B3}\left[mA/ft^2\right] = 9.29 \times 10^{-10} \int R_3(\lambda)\, W_B(\lambda)d\lambda = 5.35 \times 10^{-5}\left[mA/ft^2\right] \qquad \text{(B-5)}$$

where $K(\lambda)$ = the photopic luminosity function of the eye [L/W] Fig. A-1

$R_2(\lambda)$ = the absolute responsivity of a typical Gen2 cathode [mA/W] Fig. A-2

$R_3(\lambda)$ = the absolute responsivity of a typical Gen3 cathode [mA/W] Fig. A-3

and numeric integration was applied to calculating the integrals using Simpson's Rule at 10 nm intervals.

The results above will be used in deriving the equations for the Gen2 normalized irradiance [HN2], and the Gen3 normalized irradiance [HN3] in appendixes D and E. An estimate of the night sky spectral distribution[3] is shown for comparison in Fig. B-3.* This night sky estimate is presented to show close agreement with the measured curves of Vatsia, and lend credibility to the chosen baseline night sky distribution, $W_B(\lambda)$.

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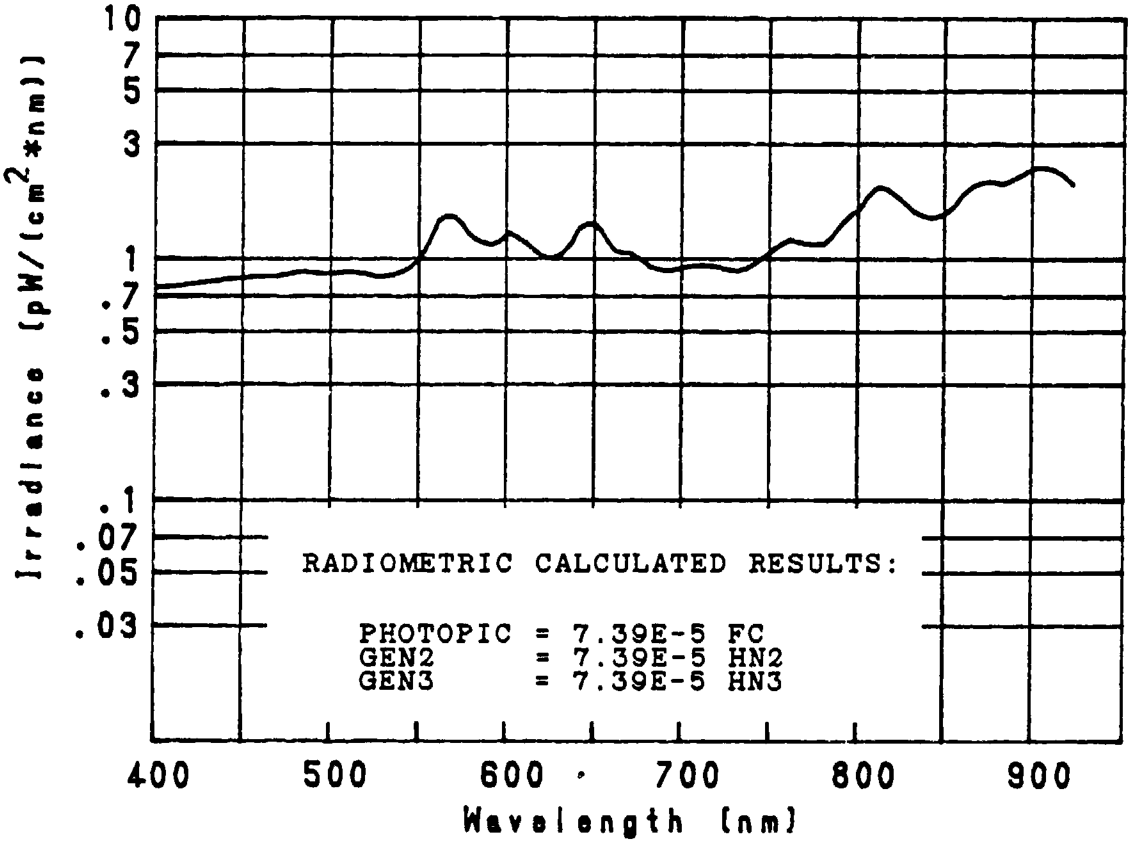
*The spectral irradiance curve as depicted in the reference is in units of photons per second. Thus, use of the Planck's conversion equation is necessary to convert the irradiance to watts: $E = hc/\lambda$, where E is the energy of a single photon, h = Planck's constant 6.626×10^{-34} [J X Sec], c = speed of light, λ = wavelength, and 1 watt = 1 J/Sec.



WAVELENGTH [nm]	SPECTRAL IRRAD. [pW/(cm^2 nm)]	WAVELENGTH [nm]	SPECTRAL IRRAD. [pW/(cm^2 nm)]
400	0.75	650	1.37
	0.77		1.09
	0.79		1.04
	0.80		0.92
	0.82		0.89
450	0.83	700	0.92
	0.84		0.93
	0.85		0.92
	0.88		0.89
	0.87		0.96
500	0.86	750	1.09
	0.88		1.20
	0.86		1.15
	0.84		1.17
	0.89		1.42
550	1.02	800	1.63
	1.44		1.99
	1.48		1.82
	1.22		1.57
	1.14		1.48
600	1.28	850	1.58
	1.15		1.91
	1.01		2.08
	1.05		2.04
	1.34		2.20
		900	2.39
			2.33
			2.04

Figure B-1. Clear Starlight (Re: Vatsia, September 1972), $W_B(\lambda)$

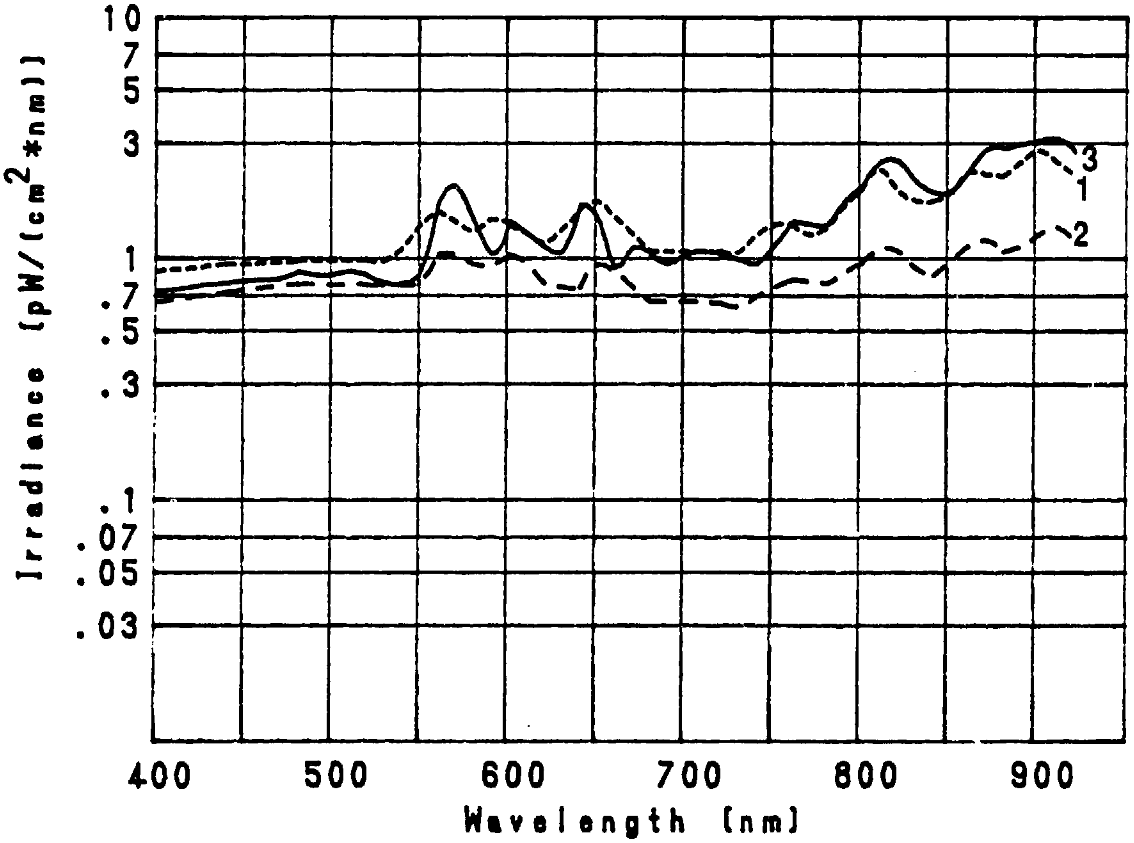
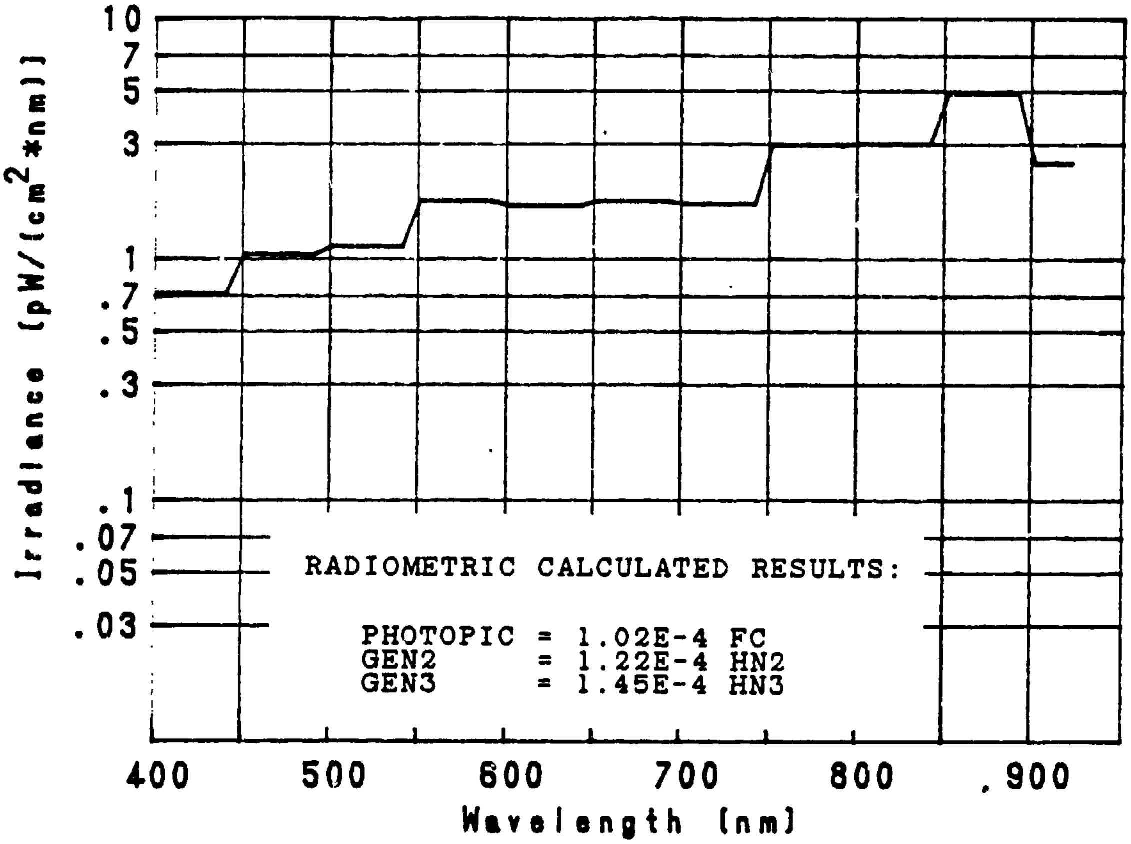


Figure B-2. Vatsia, et. al. Recordings, Clear Starlight Conditions



WAVELENGTH [nm]	SPECTRAL IRRAD. [pW/(cm^2 nm)]	WAVELENGTH [nm]	SPECTRAL IRRAD. [pW/(cm^2 nm)]
400	0.71	650	1.75
	0.71		1.75
	0.71		1.75
	0.71		1.75
	0.71		1.75
450	1.04	700	1.69
	1.04		1.69
	1.04		1.69
	1.04		1.69
	1.04		1.69
500	1.13	750	2.99
	1.13		2.99
	1.13		2.99
	1.13		2.99
	1.13		2.99
550	1.74	800	3.02
	1.74		3.02
	1.74		3.02
	1.74		3.02
	1.74		3.02
600	1.66	850	4.89
	1.66		4.89
	1.66		4.89
	1.66		4.89
	1.66		4.89
		900	2.50
			2.50
			2.50

Figure B-3. Clear Starlight (Re: RCA Handbook), Estimate

APPENDIX C
CALCULATION OF ILLUMINANCE, E (FOOTCANDLE)

Photometric units of measure, such as the footcandle, are based on the lumen as the primary unit of measure. (Note that watts is the primary unit of measure of radiometric quantities.) That part of radiant flux which has the capacity to stimulate visual sensation in the human eye is called luminous flux, and this capacity is expressed in lumens.*

The luminous flux density, more commonly referred to as illumination, is the luminous flux incident on a surface per unit area of the surface (ex. lumens/ft^2). One lumen per square foot is defined as one footcandle:

$$1\left[L/ft^2\right] = 1\ [FC] \tag{C-1}$$

The most important features of the footcandle as a unit of measure are that (1) it only has meaning in the visible portion of the electromagnetic spectrum (between 350 nm and 770 nm), and (2) it is a measure only of the apparent "brightness" as perceived by an average human eye. Thus, its value alone provides no information about the power level, color, nor spectral distribution of the incident radiation.

However, given the spectral power distribution of the incident radiation, the calculation of the luminous flux density [FC] is rather basic. The calculation is based on the absolute photopic luminosity function of the eye, $K(\lambda)$, which expresses the ratio of luminous flux (lumens) to the radiant flux (watts) in the wavelength region of the eye response. It is, therefore, a conversion factor with the dimension [L/W].

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*The lumen as a unit of measure was originally based on the brightness of a sperm candle as a standard, and more recently redefined with a new standard: the luminous flux per steradian (sr) of a blackbody radiator 1 cm^2 in area at the solidification temperature of platinum (2042 K) which is defined to emit 60 lumens per steradian. Thus, at 1 foot from the source, a 1 ft^2 area would receive 60 lumens of luminous flux (i.e., 60 FC).

Given a spectral irradiance distribution, $W(\lambda)$, the luminous flux density, (E), is calculated as follows:

$$E \left[\frac{L}{cm^2}\right] = \int K(\lambda) \left[\frac{L}{W}\right] \times W(\lambda) \left[\frac{W}{cm^2\ nm}\right] d\lambda\ [nm] \qquad (C\text{-}2)$$

Converting the units from $\left[L/cm^2\right]$ to $\left[L/ft^2\right]$ and given the identity in equation (C-1), the following is obtained:

$$E\ [FC] = 929 \left[\frac{cm^2}{ft^2}\right] \int K(\lambda) \left[\frac{L}{W}\right] \times W(\lambda) \left[\frac{W}{cm^2\ nm}\right] d\lambda\ [nm] \qquad (C\text{-}3)$$

The luminous flux density [FC] as calculated from the night sky spectral irradiance data made use of equation (C-3) as follows:

$$E\ [FC] = 9.29 \times 10^{-10} \left[\frac{cm^2}{ft^2}\ \frac{W}{pW}\right] \int K(\lambda) \left[\frac{L}{W}\right] \times W(\lambda) \left[\frac{pW}{cm^2\ nm}\right] d\lambda\ [nm] \qquad (C\text{-}4)$$

where: $W(\lambda)$ was measured using picowatts instead of watts, and the integration was performed using Simpson's Rule at 10 nm intervals.

APPENDIX D
CALCULATION OF THE GEN2 NORMALIZED IRRADIANCE, θ_{2N} (HN2)

Just as the measure of visual incident radiation [FC] is based on the photopic luminosity function of the eye, K(λ), the measure of the incident radiation perceived by a second generation (Gen2) detector should be based on the response function of such a detector. The Gen2 detector is physically comprised of the photocathode of an image intensifier tube. A typical photocathode response curve as depicted in Fig. A-2 is used to relate the <u>transfer</u> response of the detector [mA/W] as a function of wavelength. Thus, given an incident spectral power distribution of radiation, the output signal current $\left[mA/ft^2\right]$ from such a detector can be derived. Unfortunately, the output signal current of the detector is not descriptive of the incident radiation, just as the nerve impulses from the eye are not used to describe the incident radiation as perceived by the eye. Thus, a normalized unit of measure of the Gen2 incident radiation is necessary to describe the radiation as perceived by a Gen2 detector.

All units of measure need a baseline standard on which to quantify their measured values (ex: the unit of footcandle [FC] is based on the brightness of platinum at 2042 Kelvin). Since the purpose of Gen2 and Gen3 "light level" data is to be compared with the incident photopic "light level" [FC], and since these quantities are to determine the presence and amount of artificial light contamination, let the baseline standard for the measure of the nonphotopic detectors be the uncontaminated, natural, moonless, clear starlit night sky. With this baseline, adjust the amplitude of the nonphotopic detectors such that their integrated products with the baseline night sky equals the photopic integrated product [FC] with the same baseline. The results from this basis would then provide a means to interrelate the numeric values of the <u>incident</u> radiation as perceived by the eye, by a Gen2 detector, and by a Gen3 detector. For example, if the Gen2 and the Gen3 values equal that of the photopic [FC], then it can be concluded that the night sky incident radiation is distributed like that of natural clear starlight.

The derivation of the Gen2 normalized irradiance [HN2] is as follows:

Let $W_B(\lambda)$ = the incident spectral power distribution of the natural, clear starlit-only night sky $\left[pW \times cm^{-2} \times nm^{-1}\right]$ vs λ Fig. B-1

$R_2(\lambda)$ = the absolute responsivity of a typical Gen2 cathode [mA/W] vs λ Fig. A-2

θ_{B2} = the response of a typical Gen2 cathode $\left[mA/ft^2\right]$ to W_B

$K(\lambda)$ = the photopic luminosity function of the eye [L/W] vs λ Fig. A-1

E_B = luminous flux density [FC] or $\left[L/ft^2\right]$ of $W_B(\lambda)$

Then

$$E_B[FC] = E_B\left[L/ft^2\right] = 9.29 \times 10^{-10} \int K(\lambda) \times W_B(\lambda)d\lambda \qquad \text{(D-1)}$$

from equation (C-4)

And

$$\theta_{B2}\left[mA/ft^2\right] = 9.29 \times 10^{-10} \int R_2(\lambda) \times W_B(\lambda)d\lambda \qquad \text{(D-2)}$$

Now let $R_{2N}(\lambda)$ = the normalized responsivity of a Gen2 cathode [L2/W] vs λ

θ_{2N} = the normalized response of a Gen2 cathode [HN2]

C_2 = the factor of normalization

Then

$$\theta_{2N}[HN2] = 9.29 \times 10^{-10} \int R_{2N}(\lambda) \times W_B(\lambda)d\lambda \qquad \text{(D-3)}$$

Where $$R_{2N}(\lambda) = C_2 \times R_2(\lambda) \tag{D-4}$$

Therefore $$\theta_{2N}[HN2] = 9.29 \times 10^{-10} \int C_2 \times R_2(\lambda) \times W_B(\lambda)d\lambda \tag{D-5}$$

And $$\theta_{2N}[HN2] = C_2 \times \theta_{B2} \left[mA/ft^2\right] \tag{D-6}$$

Where the unit of C_2 is $\left[HN2 \times ft^2 \times mA^{-1}\right]$

To determine the value of the constant C_2

Let $E_B = \theta_{2N}$ using equation (D-1) and equation (D-4) as follows:

$$9.29 \times 10^{-10} \quad K(\lambda)W_B(\lambda)d\lambda = C_2 \times 9.29 \times 10^{-10} \int R_2(\lambda)W_B(\lambda)d\lambda \tag{D-7}$$

Therefore $$C_2 = \frac{9.29 \times 10^{-10} \int K(\lambda)W_B(\lambda)d\lambda}{9.29 \times 10^{-10} \int R_2(\lambda)W_B(\lambda)d\lambda} \left[\frac{HN2}{mA/ft^2}\right] \tag{D-8}$$

The constant, C_2, can now be calculated from the eye response, $K(\lambda)$, the Gen2 absolute responsivity, $R_2(\lambda)$, and the baseline night sky, $W_B(\lambda)$, as follows:

$$C_2 = \frac{E_B}{\theta_{B2}} \quad \text{from equations (D-1), (D-2), (D-8)} \tag{D-9}$$

$$E_B = 9.29 \times 10^{-10} \int K(\lambda)W_B(\lambda)d\lambda = 7.39 \times 10^{-5} \text{ [FC]}$$
from equation (B-3) (D-10)

$$\theta_{B2} = 9.29 \times 10^{-10} \int R_2(\lambda)W_B(\lambda)d\lambda = 1.82 \times 10^{-5} \left[mA/ft^2\right]$$
from equation (B-4) (D-11)

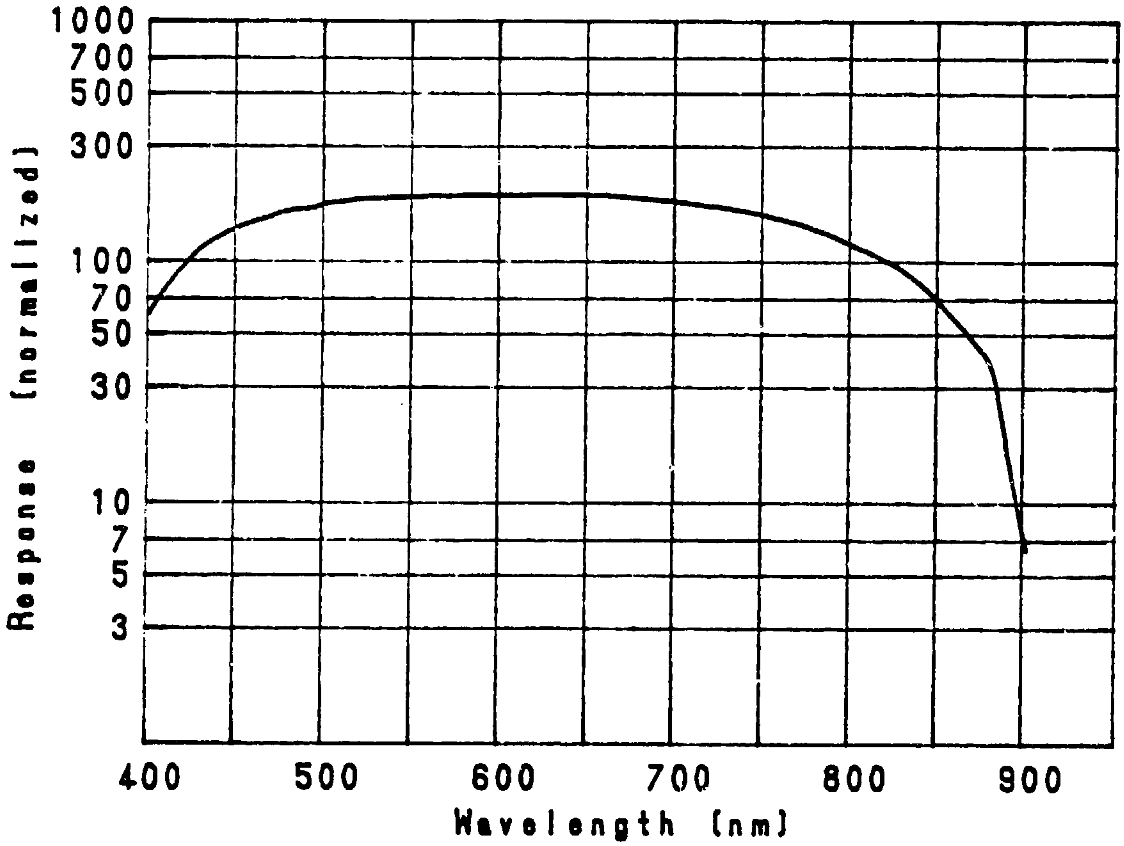
Therefore $$C_2 = 4.06 \left[\frac{HN2 \times ft^2}{mA}\right] \tag{D-12}$$

Thus, for any night sky distribution, $W(\lambda)$, the calculation of the normalized response of a Gen2 cathode [HN2] is as follows:

$$\Theta_{2N}\ [HN2] = 9.29 \times 10^{-10} \int R_{2N}(\lambda) \times W(\lambda) d\lambda \tag{D-13}$$

where $$R_{2N}(\lambda) = 4.06\ R_2(\lambda),\ \text{and}\ \Theta_{2N} = E\ \text{if}\ W(\lambda) = W_B(\lambda) \tag{D-14}$$

The Gen2 normalized detector response, $R_{2N}(\lambda)$, is shown in Fig. D-1.



WAVELENGTH [nm]	RESPONSE [normalized]	WAVELENGTH [nm]	RESPONSE [normalized]
400	60.16	650	189.28
	78.47		188.28
	94.97		185.95
	114.14		183.62
	126.69		180.72
450	137.92	700	177.34
	147.24		173.58
	154.56		169.45
	163.07		166.45
	166.45		161.46
500	174.15	750	155.99
	176.91		148.81
	182.10		142.67
	183.57		134.54
	185.24		126.03
550	185.95	800	117.18
	186.76		107.95
	187.38		99.73
	188.28		89.41
	188.33		79.18
600	188.33	850	66.58
	189.28		55.40
	189.99		45.66
	189.99		34.81
	189.94		14.27
		900	6.37
			0.00
			0.00

Figure D-1. Gen2 Normalized Detector Response, $R_{2N}(\lambda)$

APPENDIX E
CALCULATION OF THE GEN3 NORMALIZED IRRADIANCE, θ_{3N} (HN3)

The argument for establishing a normalized unit of measure for the Gen3 incident radiation is the same as that for the Gen2. (See Appendix D.) The same baseline standard for computing the Gen3 value must be used as for the Gen2 value: the uncontaminated, natural, moonless, clear starlit night sky having an incident spectral power distribution $W_B(\lambda)$.

The derivation of the Gen3 normalized irradiance [HN3] is similar to that of HN2 as follows:

Let $W_B(\lambda)$ = the incident spectral power distribution of the natural, clear starlit-only night sky $\left[pW \times cm^{-2} \times nm^{-1}\right]$ vs λ

$R_3(\lambda)$ = the absolute responsivity of a typical Gen3 cathode [mA/W] vs λ

θ_{B3} = the response of a typical Gen3 cathode $\left[mA/ft^2\right]$ to $W_B(\lambda)$

$K(\lambda)$ = the photopic luminosity function of the eye [L/W] vs λ

E_B = the luminous flux density [FC] or $\left[L/ft^2\right]$ of W_B

Then

$$E_B[FC] = E_B\left[L/ft^2\right] = 9.29 \times 10^{-10} \int K(\lambda) \times W_B(\lambda)d\lambda$$

from equation (C-4) (E-1)

$$\theta_{B3}\left[mA/ft^2\right] = 9.29 \times 10^{-10} \int R_3(\lambda)W_B(\lambda)d\lambda \qquad \text{(E-2)}$$

Now let $R_{3N}(\lambda)$ = the normalized responsivity of a Gen3 cathode [L3/W] vs λ

θ_{3N} = the normalized response of a Gen3 cathode [HN3]

C_3 = the factor of normalization

Then
$$\theta_{3N}[HN3] = 9.29 \times 10^{-10} \int R_{3N}(\lambda) \times W_B(\lambda)d\lambda \quad (E-3)$$

Where
$$R_{3N}(\lambda) = C_3 \times R_3(\lambda) \quad (E-4)$$

Therefore
$$\theta_{3N}[HN3] = 9.29 \times 10^{-10} \int C_3 \times R_3(\lambda) \times W_B(\lambda)d\lambda \quad (E-5)$$

And
$$\theta_{3N}[HN3] = C_3 \times \theta_{B3} \left[mA/ft^2\right] \quad (E-6)$$

To determine the value of the constant C_3

Let $E_B = \theta_{3N}$ using equation (E-1) and equation (E-5)

$$9.29 \times 10^{-10} \int K(\lambda)W_B(\lambda)d\lambda = C_3 \times 9.29 \times 10^{-10} \int R_3(\lambda)W_B(\lambda)d\lambda \quad (E-7)$$

Therefore
$$C_3 = \frac{9.29 \times 10^{-10} \int K(\lambda)W_B(\lambda)d\lambda}{9.29 \times 10^{-10} \int R_3(\lambda)W_B(\lambda)d\lambda} \left[\frac{HN3}{mA/ft^2}\right] \quad (E-8)$$

The constant C_3 can now be calculated from the eye response, $K(\lambda)$, the Gen3 absolute responsivity, $R_3(\lambda)$, and the baseline night sky, $W_B(\lambda)$ as follows:

$$C_3 = \frac{E_B}{\theta_{B3}}$$ from equation (E-1), (E-2), (E-8) (E-9)

$$E_B = 9.29 \times 10^{-10} \int K(\lambda)W_B(\lambda)d\lambda = 7.39 \times 10^{-5} \text{ [FC]}$$
from equation B-3 (E-10)

$$\theta_{B3} = 9.29 \times 10^{-10} \int R_3(\lambda)W_B(\lambda)d\lambda = 5.35 \times 10^{-5} \left[mA/ft^2\right]$$
from equation (B-5) (E-11)

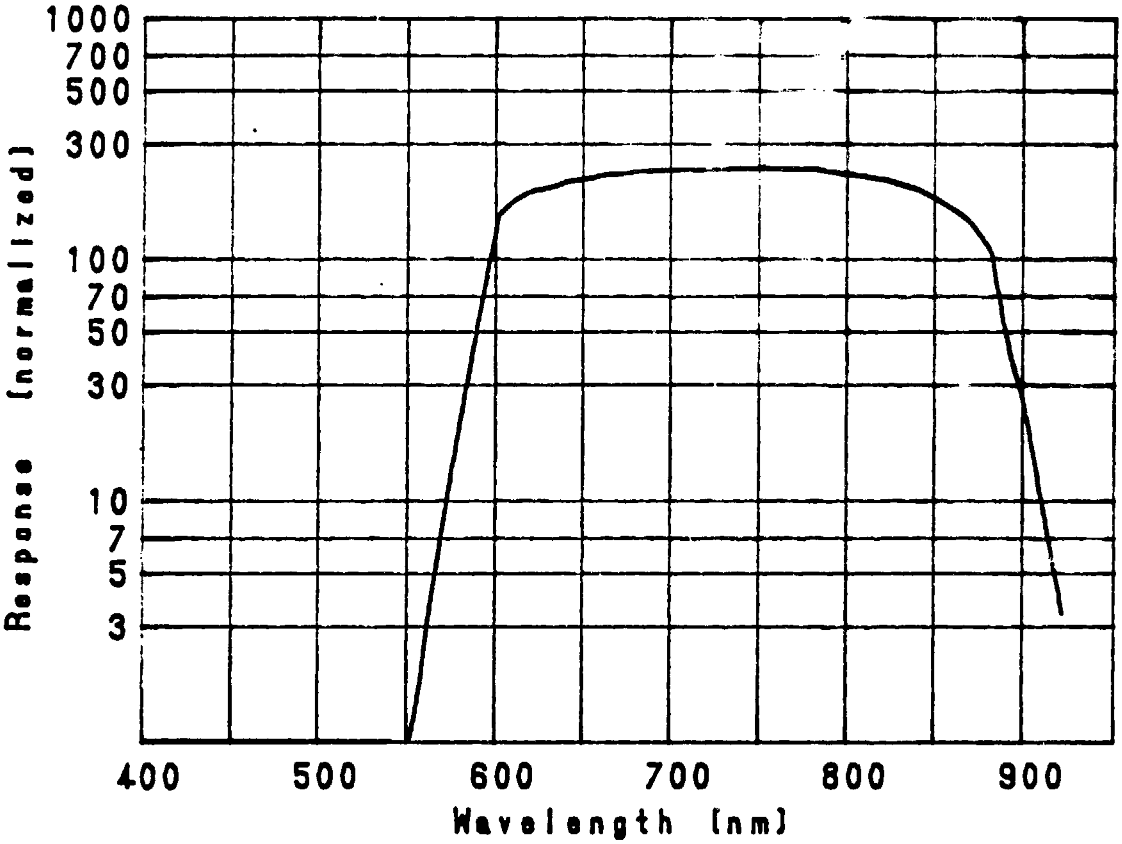
Therefore $C_3 = 1.38 \left[\dfrac{\text{HN3 X ft}^2}{\text{mA}}\right]$ (E-12)

Thus, for any night sky distribution, $W(\lambda)$, the calculation of the normalized response of a Gen3 cathode [HN3] is as follows:

$$\theta_{3N}[\text{HN3}] = 9.29 \text{ X } 10^{-10} \int R_{3N}(\lambda) \text{ X } W(\lambda) d\lambda \qquad \text{(E-13)}$$

Where $R_{3N}(\lambda) = 1.38 \text{ X } R_{3}(\lambda)$, and $\theta_{3N} = E$ if $W(\lambda) = W_B(\lambda)$ (E-14)

The Gen3 normalized detector response, $R_{3N}(\lambda)$, is shown in Fig. E-1.



WAVELENGTH [nm]	RESPONSE [normalized]	WAVELENGTH [nm]	RESPONSE [normalized]
400	0.00	650	216.31
	0.00		223.66
	0.00		227.93
	0.00		232.13
	0.00		233.83
450	0.00	700	235.53
	0.00		236.33
	0.00		237.22
	0.00		238.12
	0.00		238.90
500	0.00	750	238.90
	0.00		238.90
	0.00		238.12
	0.00		237.22
	0.00		231.32
550	0.00	800	225.35
	2.88		219.35
	8.94		213.50
	23.72		202.54
	62.57		191.46
600	152.49	850	175.19
	176.98		157.32
	193.16		135.86
	200.22		107.26
	211.80		42.90
		900	22.02
			8.94
			3.40

Figure E-1. Gen3 Normalized Detector Response, $R_{3N}(\lambda)$

APPENDIX F
CALCULATION OF PERCENT ARTIFICIAL CONTRIBUTION, P_A

An analysis of the artificial and natural contributions to the total irradiance measurement is indicative of the suitability of a location for testing the performance differences between the two technologies of Generation two and Generation three systems.[1] An accurate analysis would be possible only if separate irradiance measurements could be made with and without the presence of artificial lighting. Since this would be impossible, one assumption that must be made is that the natural night sky contribution is equivalent to the baseline night sky, $W_B(\lambda)$ (Fig. B-1). As such, the artificial contribution analysis can only be made during a moonless condition since the moon's contribution to the total irradiance is unknown, and the baseline night sky is itself that of a moonless condition.

Therefore, let

H_T = the total integrated irradiance measured [FC] or [HN2] or [HN3]

H_N = the natural-only contribution to the total

H_A = the artificial contribution to the total

Then $$H_T = H_N + H_A \qquad \text{(F-1)}$$

Now let P_A = the percent artificial contribution to H_T

Then $$P_A = \frac{H_A}{H_T} \times 100\% \qquad \text{(F-2)}$$

Or $$P_A = \frac{H_T - H_N}{H_T} \times 100\% \qquad \text{(F-3)}$$

Assume H_N = the baseline night sky (Fig. B-1)

Then $H_N = 7.39 \times 10^{-5}$ [FC] or [HN2] or [HN3]

Therefore $$P_A = \frac{H_T - 7.39 \times 10^{-5}}{H_T} \times 100\% \qquad \text{(F-4)}$$

Thus, for the photopic spectral band, where $H_T = E[FC]$:

$$P_A = \frac{E[FC] - 7.39 \times 10^{-5}}{E[FC]} \times 100\% \qquad \text{(F-5)}$$

For the Gen2 spectral band, where $H_T = \theta_{2N}[HN2]$

$$P_A = \frac{\theta_{2N}[HN2] - 7.39 \times 10^{-5}}{\theta_{2N}[HN2]} \times 100\% \qquad \text{(F-6)}$$

And for the Gen3 spectral band where $H_T = \theta_{3N}[HN3]$

$$P_A = \frac{\theta_{3N}[HN3] - 7.39 \times 10^{-5}}{\theta_{3N}[HN3]} \times 100\% \qquad \text{(F-7)}$$

where P_A = percent artificial contribution to the total irradiance in each respective spectral band

APPENDIX G
STANDARD SOURCE FOR CALIBRATION

For the purpose of calibrating the NSR in the field, a standard, calibrated light source was included as part of the instrumentation. The source is a model RS-65/C manufactured by Hoffman Engineering Corp., and has a certified calibration by the manufacturer (Table G-1). The calibration provides the spectral radiance of the source at 5nm intervals from 350nm to 1,000nm, and with the light source monitor set at 1% (i.e., monitor reading 1.00).

TABLE G-1. Calibrated Light Source Spectral Radiance Data

SPECTRAL RADIANCE DATA
DEVICE : RS-65/C SER. NR. 437
DATE: 5-6-86 POINT MEASURED: 1

TRISTIMULUS VALUES				CIE CHROMATICITY COORDINATES			COLOR TEMP
Xblue	Xred	Y	Z	x	y	z	KELVINS
.942	.895	.850	.285	.4505	.4127	.1368	2853

LUMINANCE VALUES:
8.557 Footlamberts OPERATING VOLTAGE: 9.945 VOLTS
.002932 Cd/CM^2 MONITOR READING: 1.00
29.32 Cd/M^2

WAVELENGTH (ANGSTROMS)	SPECTRAL RADIANCE (uWATTS/CM^2-STR-nm)	RELATIVE SPECTRAL RADIANCE (%)
3500	9.292E-04	.95
3550	1.267E-03	1.29
3600	1.537E-03	1.57
3650	1.919E-03	1.95
3700	2.261E-03	2.30
3750	2.575E-03	2.62
3800	2.954E-03	3.01
3850	3.369E-03	3.43
3900	3.854E-03	3.93
3950	4.334E-03	4.42
4000	4.967E-03	5.06
4050	5.426E-03	5.53
4100	6.016E-03	6.13
4150	6.694E-03	6.82
4200	7.292E-03	7.43
4250	8.004E-03	8.15
4300	8.737E-03	8.90
4350	9.478E-03	9.66
4400	1.030E-02	10.49
4450	1.119E-02	11.40
4500	1.206E-02	12.29
4550	1.297E-02	13.21
4600	1.405E-02	14.31
4650	1.501E-02	15.29
4700	1.620E-02	16.51
4750	1.719E-02	17.51
4800	1.837E-02	18.71
4850	1.950E-02	19.86
4900	2.081E-02	21.20
4950	2.201E-02	22.43
5000	2.336E-02	23.80
5050	2.454E-02	25.00
5100	2.599E-02	26.48
5150	2.732E-02	27.83
5200	2.878E-02	29.32
5250	3.005E-02	30.61
5300	3.162E-02	32.21
5350	3.301E-02	33.63
5400	3.442E-02	35.06
5450	3.593E-02	36.60
5500	3.730E-02	38.00
5550	3.875E-02	39.47
5600	4.025E-02	41.00
5650	4.156E-02	42.34
5700	4.297E-02	43.77
5750	4.439E-02	45.22

CERTIFICATION

TABLE G-1. Calibrated Light Source Spectral Radiance Data (Continued)

WAVELENGTH (ANGSTROMS)	SPECTRAL RADIANCE (uWATTS/CM^2-STR-nm)	RELATIVE SPECTRAL RADIANCE (%)
5800	4.588E-02	46.74
5850	4.740E-02	48.29
5900	4.878E-02	49.70
5950	5.015E-02	51.09
6000	5.144E-02	52.41
6050	5.273E-02	53.72
6100	5.401E-02	55.02
6150	5.543E-02	56.47
6200	5.667E-02	57.74
6250	5.783E-02	58.92
6300	5.912E-02	60.23
6350	6.046E-02	61.60
6400	6.160E-02	62.75
6450	6.285E-02	64.03
6500	6.401E-02	65.21
6550	6.533E-02	66.55
6600	6.650E-02	67.74
6650	6.782E-02	69.09
6700	6.895E-02	70.25
6750	7.024E-02	71.55
6800	7.132E-02	72.65
6850	7.268E-02	74.04
6900	7.388E-02	75.26
6950	7.532E-02	76.73
7000	7.560E-02	77.01
7050	7.770E-02	79.16
7100	7.865E-02	80.13
7150	7.962E-02	81.12
7200	8.069E-02	82.20
7250	8.165E-02	83.18
7300	8.263E-02	84.18
7350	8.390E-02	85.47
7400	8.470E-02	86.29
7450	8.537E-02	86.98
7500	8.670E-02	88.32
7550	8.747E-02	89.11
7600	8.840E-02	90.06
7650	8.902E-02	90.69
7700	9.007E-02	91.76
7750	9.078E-02	92.49
7800	9.120E-02	92.91
7850	9.190E-02	93.62
7900	9.268E-02	94.42
7950	9.346E-02	95.21
8000	9.408E-02	95.84
8050	9.428E-02	96.02
8100	9.470E-02	96.47
8150	9.528E-02	97.06
8200	9.564E-02	97.43
8250	9.623E-02	98.04
8300	9.645E-02	98.26
8350	9.652E-02	98.33
8400	9.678E-02	98.60
8450	9.712E-02	98.94
8500	9.731E-02	99.13

TABLE G-1. Calibrated Light Source Spectral Radiance Data (Continued)

WAVELENGTH (ANGSTROMS)	SPECTRAL RADIANCE (uWATTS/CM^2-STR-nm)	RELATIVE SPECTRAL RADIANCE (%)
8550	9.774E-02	99.57
8600	9.752E-02	99.35
8650	9.731E-02	99.13
8700	9.765E-02	99.48
8750	9.790E-02	99.74
8800	9.797E-02	99.81
8850	9.798E-02	99.81
8900	9.804E-02	99.88
8950	9.814E-02	99.98
9000	9.810E-02	99.94
9050	9.816E-02	100.00
9100	9.802E-02	99.85
9150	9.790E-02	99.73
9200	9.789E-02	99.72
9250	9.783E-02	99.67
9300	9.746E-02	99.29
9350	9.743E-02	99.25
9400	9.722E-02	99.04
9450	9.698E-02	98.80
9500	9.738E-02	99.20
9550	9.629E-02	98.09
9600	9.599E-02	97.79
9650	9.543E-02	97.22
9700	9.616E-02	97.96
9750	9.584E-02	97.63
9800	9.539E-02	97.18
9850	9.532E-02	97.10
9900	9.543E-02	97.22
9950	9.517E-02	96.95
10000	9.426E-02	96.03

HOFFMAN ENGINEERING CORP.
STAMFORD, CT. 06902
JOB NUMBER: 7309

CERTIFIED BY: Craig A. McCarty
DATE: 5-6-86

ANVIS RADIANCE PRODUCT IS:2.00E-05 WATTS PER CM SQ-STR

ANVIS RADIANCE PRODUCT IS:2.34E-07 WATTS PER CM SQ-STR
FOR A 0.1 FOOTLAMBERT LUMINANCE LEVEL AT THE MEASURED S.E.D.

CERTIFICATION

APPENDIX H
NIGHT SKY SPECTRAL IRRADIANCE PLOTS AND METEOROLOGICAL DATA

FOE AN/PVS-7 (A,B)
FT. BENNING, GA

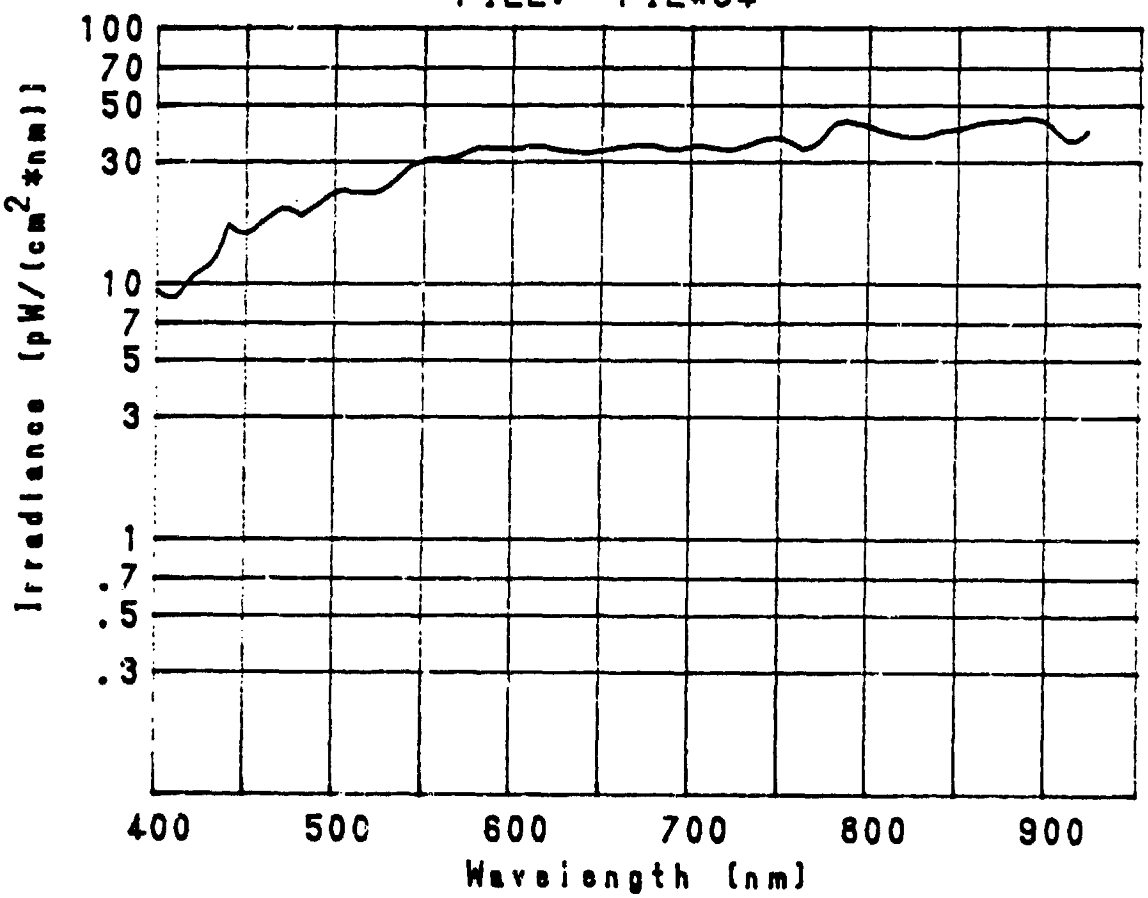
NIGHT SKY RADIOMETRIC DATA

DATE:	10-21-86
TIME:	2200
SITE:	GRISWOLD:BH
CLOUD COVER:	SCT
CLOUD ALT. (FT):	20K
MOON INCLINATION (DEG):	11
MOON AZIMUTH (DEG):	70
MOON PHASE:	82%WAN
REF. PANEL AZIMUTH (DEG):	350
REF. PANEL INCL. (DEG):	45
REL. HUMIDITY (%):	67
TEMPERATURE (F):	52

RADIOMETRIC CALCULATED RESULTS:

PHOTOPIC = 1.97E-3 FC
GEN2 = 2.03E-3 HN2
GEN3 = 2.10E-3 HN3

FILE: FIL#C4



FOE AN/PVS-7(A,B)
FT. BENNING, GA

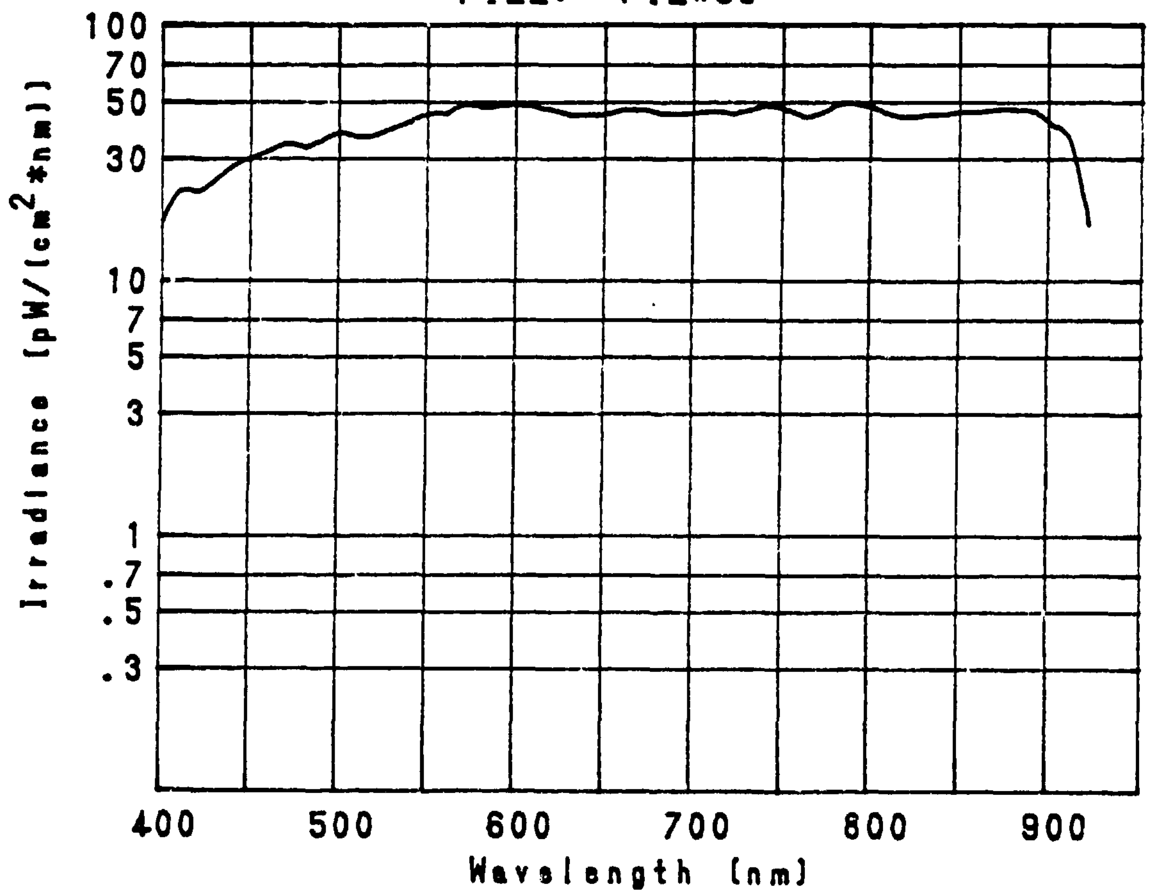
NIGHT SKY RADIOMETRIC DATA

DATE:	10-21-86
TIME:	2300
SITE:	GRISWOLD:BH
CLOUD COVER:	SCT
CLOUD ALT.(FT):	20K
MOON INCLINATION(DEG):	28
MOON AZIMUTH(DEG):	70
MOON PHASE:	82%WAN
REF. PANEL AZIMUTH(DEG):	350
REF. PANEL INCL.(DEG):	45
REL. HUMIDITY (%):	66
TEMPERATURE (F):	50

RADIOMETRIC CALCULATED RESULTS:

PHOTOPIC = 2.94E-3 FC
GEN2 = 2.83E-3 HN2
GEN3 = 2.64E-3 HN3

FILE: FIL#C5



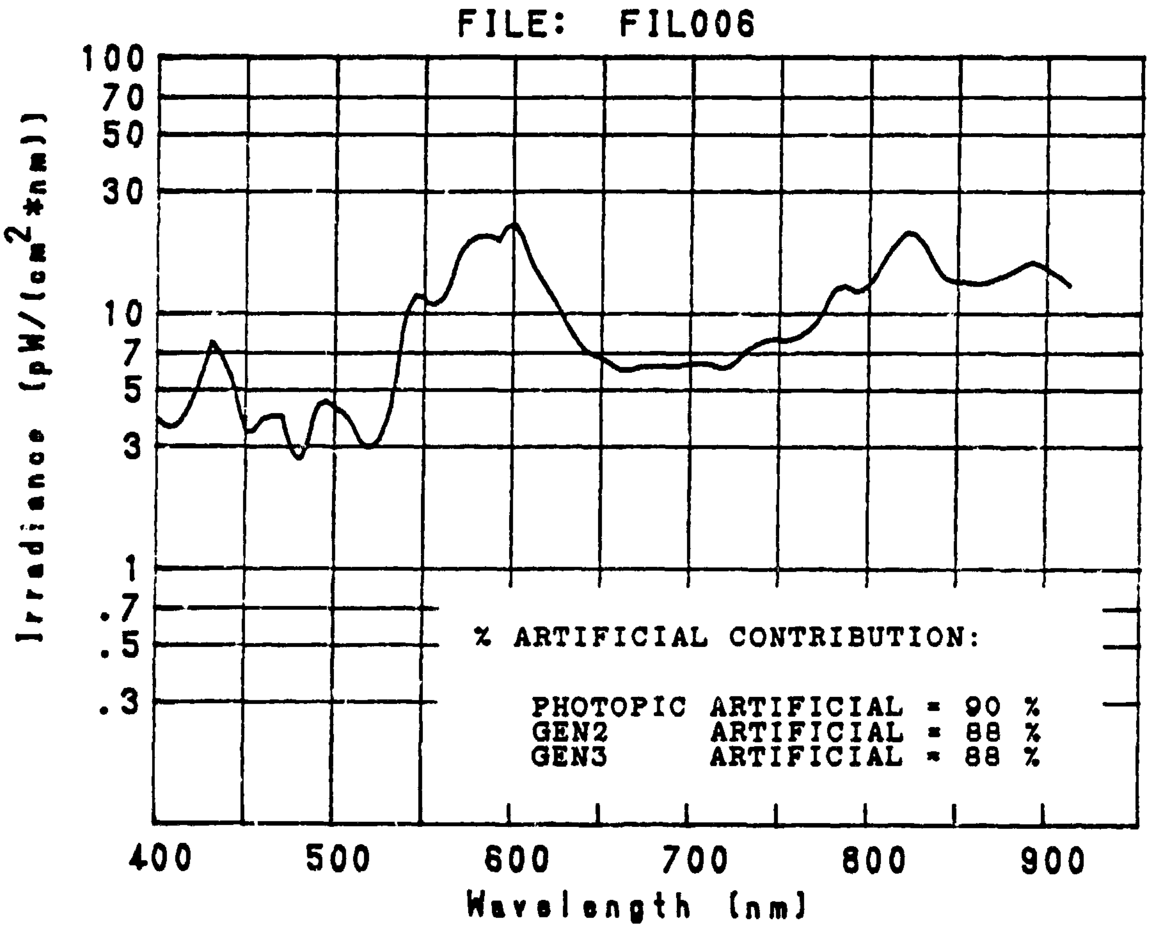
FOE AN/PVS-7(A,B)
FT. BENNING, GA

NIGHT SKY RADIOMETRIC DATA

DATE:	10-22-86
TIME:	1940
SITE:	GRISWOLD:BH
CLOUD COVER:	SCT BKN BKN
CLOUD ALT. (FT):	15K 20K 25K
MOON INCLINATION(DEG):	N/A
MOON AZIMUTH(DEG):	N/A
MOON PHASE:	N/A
REF. PANEL AZIMUTH(DEG):	350
REF. PANEL INCL. (DEG):	45
REL. HUMIDITY (%):	68
TEMPERATURE (F):	60

RADIOMETRIC CALCULATED RESULTS:

PHOTOPIC = 7.68E-4 FC
GEN2 = 6.16E-4 HN2
GEN3 = 6.12E-4 HN3



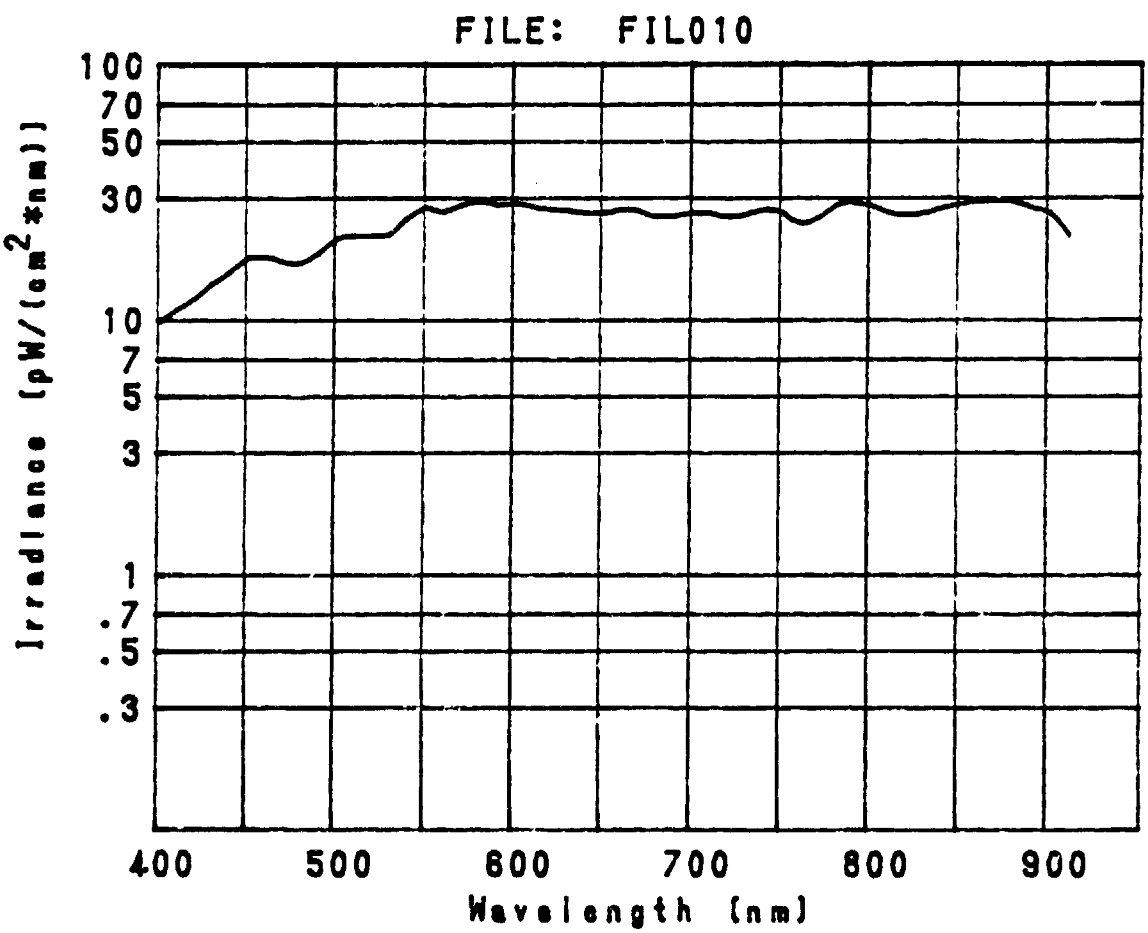
FOE AN/PVS-7(A,B)
FT. BENNING, GA

NIGHT SKY RADIOMETRIC DATA

DATE:	10-23-86
TIME:	0005
SITE:	GRISWOLD:BH
CLOUD COVER:	SCT
CLOUD ALT.(FT):	25K
MOON INCLINATION(DEG):	20
MOON AZIMUTH(DEG):	70
MOON PHASE:	84%WAN
REF. PANEL AZIMUTH(DEG):	350
REF. PANEL INCL.(DEG):	45
REL. HUMIDITY (%):	66
TEMPERATURE (F):	49

RADIOMETRIC CALCULATED RESULTS:

PHOTOPIC = 1.71E-3 FC
GEN2 = 1.62E-3 HN2
GEN3 = 1.53E-3 HN3



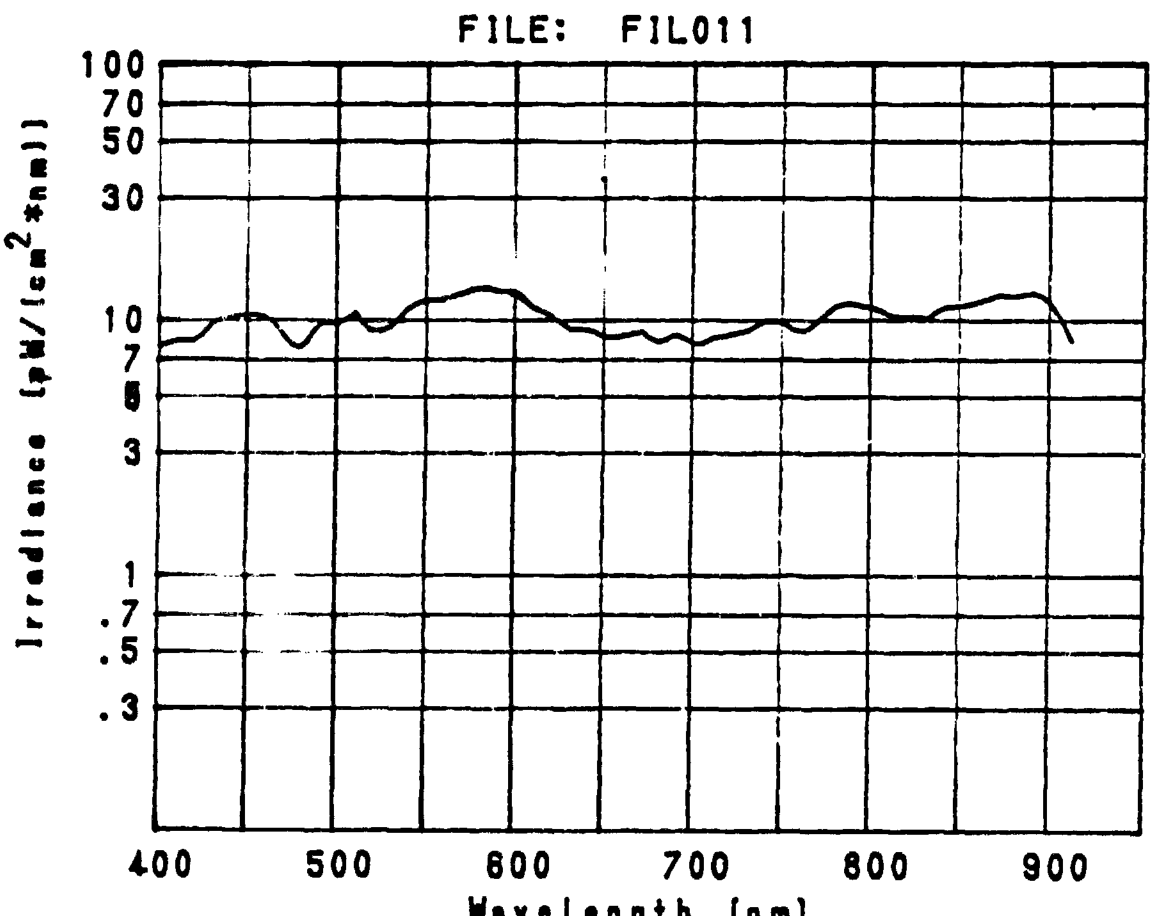
FOE AN/PVS-7 (A, B)
FT. BENNING, GA

NIGHT SKY RADIOMETRIC DATA

DATE:	10-23-86
TIME:	0035
SITE:	GRISWOLD:BH
CLOUD COVER:	SCT
CLOUD ALT. (FT):	25K
MOON INCLINATION(DEG):	27
MOON AZIMUTH(DEG):	70
MOON PHASE:	84%WAN
REF. PANEL AZIMUTH(DEG):	315
REF. PANEL INCL. (DEG):	45
REL. HUMIDITY (%):	65
TEMPERATURE (F):	49

RADIOMETRIC CALCULATED RESULTS:

PHOTOPIC = 7.51E-4 FC
GEN2 = 6.71E-4 HN2
GEN3 = 5.72E-4 HN3



FOE AN/PVS-7(A,B)
FT. BENNING, GA

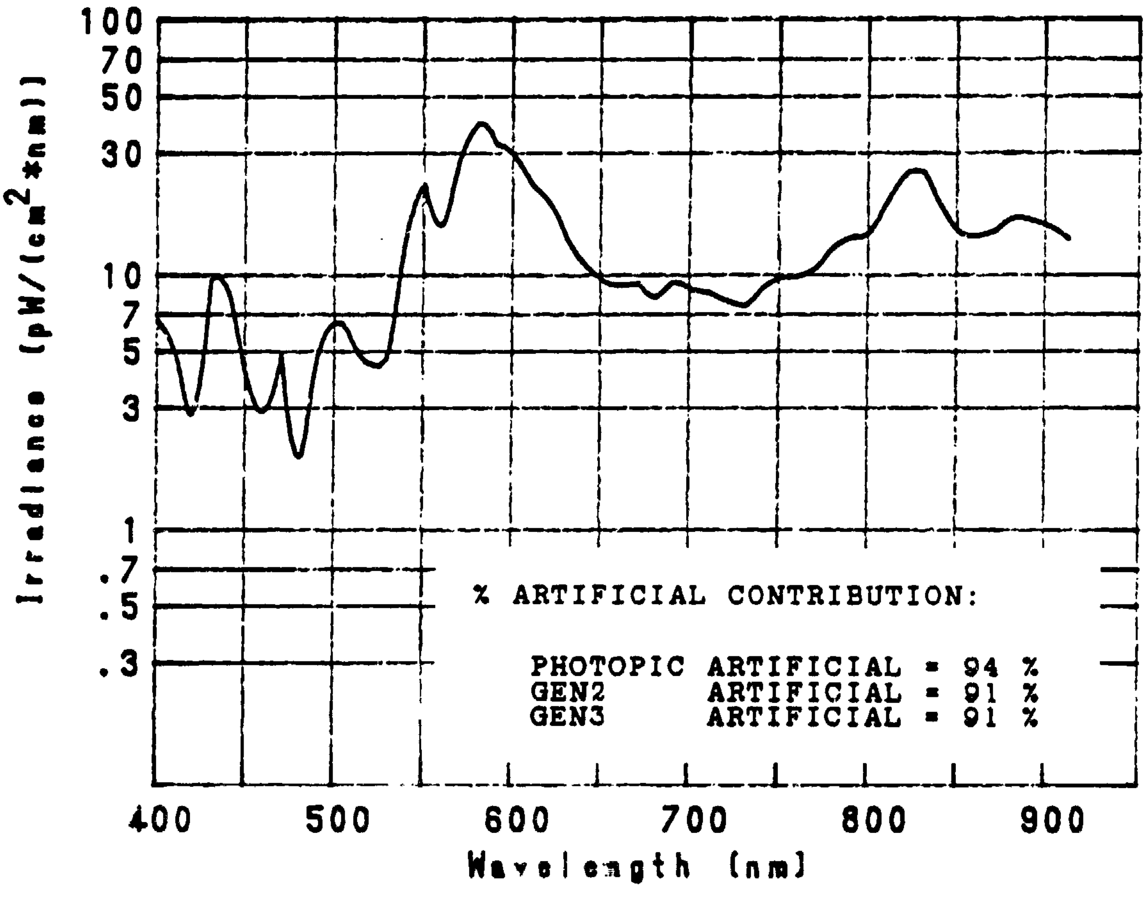
NIGHT SKY RADIOMETRIC DATA

DATE:	10-23-86
TIME:	2030
SITE:	GRISWOLD, BH
CLOUD COVER:	OVC
CLOUD ALT. (FT):	7K
MOON INCLINATION(DEG):	N/A
MOON AZIMUTH(DEG):	N/A
MOON PHASE:	N/A
REF. PANEL AZIMUTH(DEG):	262
REF. PANEL INCL. (DEG):	45
REL. HUMIDITY (%):	69
TEMPERATURE (F):	63

RADIOMETRIC CALCULATED RESULTS:

PHOTOPIC = 1.24E-3 FC
GEN2 = 8.62E-4 HN2
GEN3 = 7.82E-4 HN3

FILE: FIL013



FOE AN/PVS-7(A,B)
FT. BENNING, GA

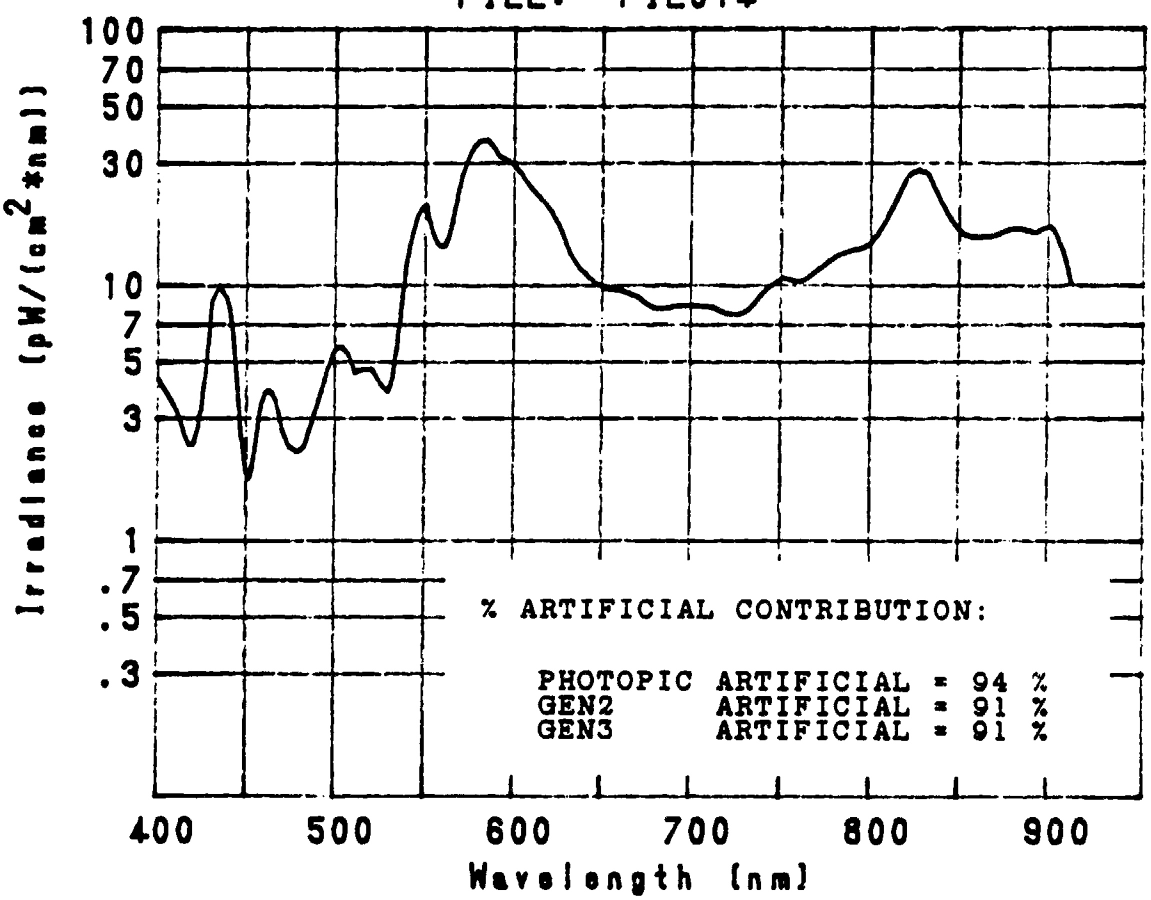
NIGHT SKY RADIOMETRIC DATA

DATE:	10-23-86
TIME:	2130
SITE:	GRISWOLD:BH
CLOUD COVER:	OVC
CLOUD ALT.(FT):	7K
MOON INCLINATION(DEG):	N/A
MOON AZIMUTH(DEG):	N/A
MOON PHASE:	N/A
REF. PANEL AZIMUTH(DEG):	262
REF. PANEL INCL.(DEG):	45
REL. HUMIDITY (%):	69
TEMPERATURE (F):	62

RADIOMETRIC CALCULATED RESULTS:

PHOTOPIC = 1.18E-3 FC
GEN2 = 8.39E-4 HN2
GEN3 = 8.01E-4 HN3

FILE: FIL014



FOE AN/PVS-7(A,B)
FT. BENNING, GA

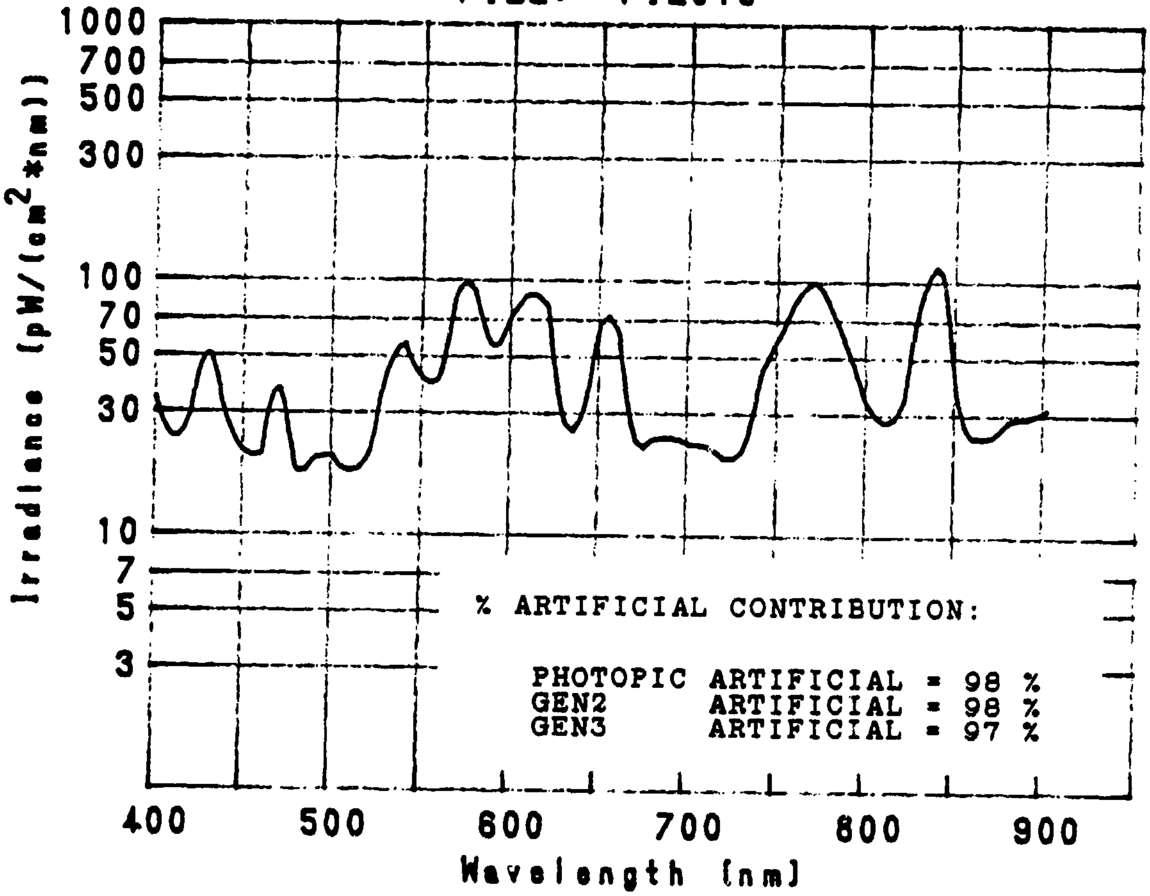
NIGHT SKY RADIOMETRIC DATA

DATE:	10-27-86
TIME:	1821
SITE:	SIMPSON
CLOUD COVER:	SCT
CLOUD ALT.(FT):	4K
MOON INCLINATION(DEG):	N/A
MOON AZIMUTH(DEG):	N/A
MOON PHASE:	N/A
REF. PANEL AZIMUTH(DEG):	330
REF. PANEL INCL.(DEG):	45
REL. HUMIDITY (%):	60
TEMPERATURE (F):	64

RADIOMETRIC CALCULATED RESULTS:

PHOTOPIC = 3.57E-3 FC
GEN2 = 2.99E-3 HN2
GEN3 = 2.76E-3 HN3

FILE: FIL016



FOE AN/PVS-7(A,B)
FT. BENNING, GA

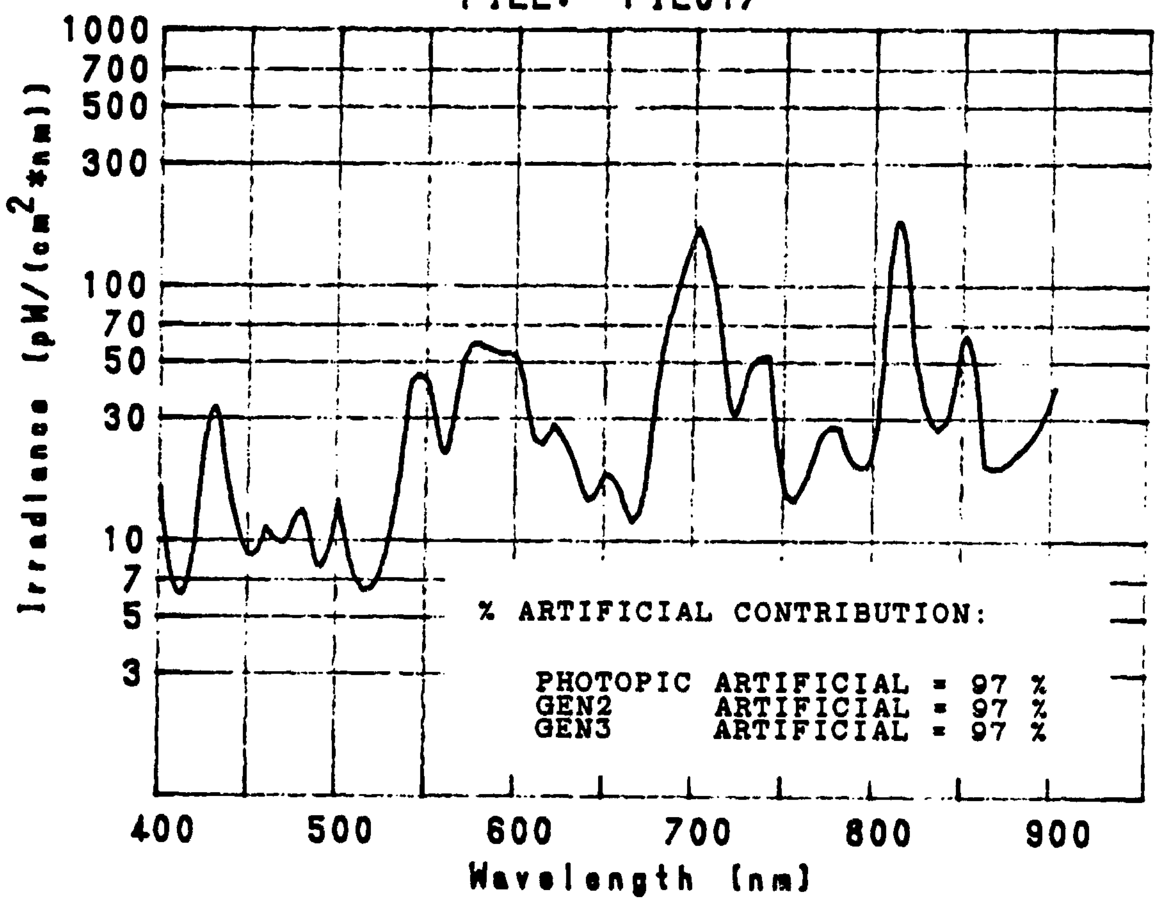
NIGHT SKY RADIOMETRIC DATA

DATE:	10-27-86
TIME:	1927
SITE:	SIMPSON
CLOUD COVER:	0
CLOUD ALT.(FT):	N/A
MOON INCLINATION(DEG):	N/A
MOON AZIMUTH(DEG):	N/A
MOON PHASE:	N/A
REF. PANEL AZIMUTH(DEG):	330
REF. PANEL INCL.(DEG):	45
REL. HUMIDITY (%):	60
TEMPERATURE (F):	64

RADIOMETRIC CALCULATED RESULTS:

PHOTOPIC = 2.14E-3 FC
GEN2 = 2.41E-3 HN2
GEN3 = 2.67E-3 HN3

FILE: FIL017



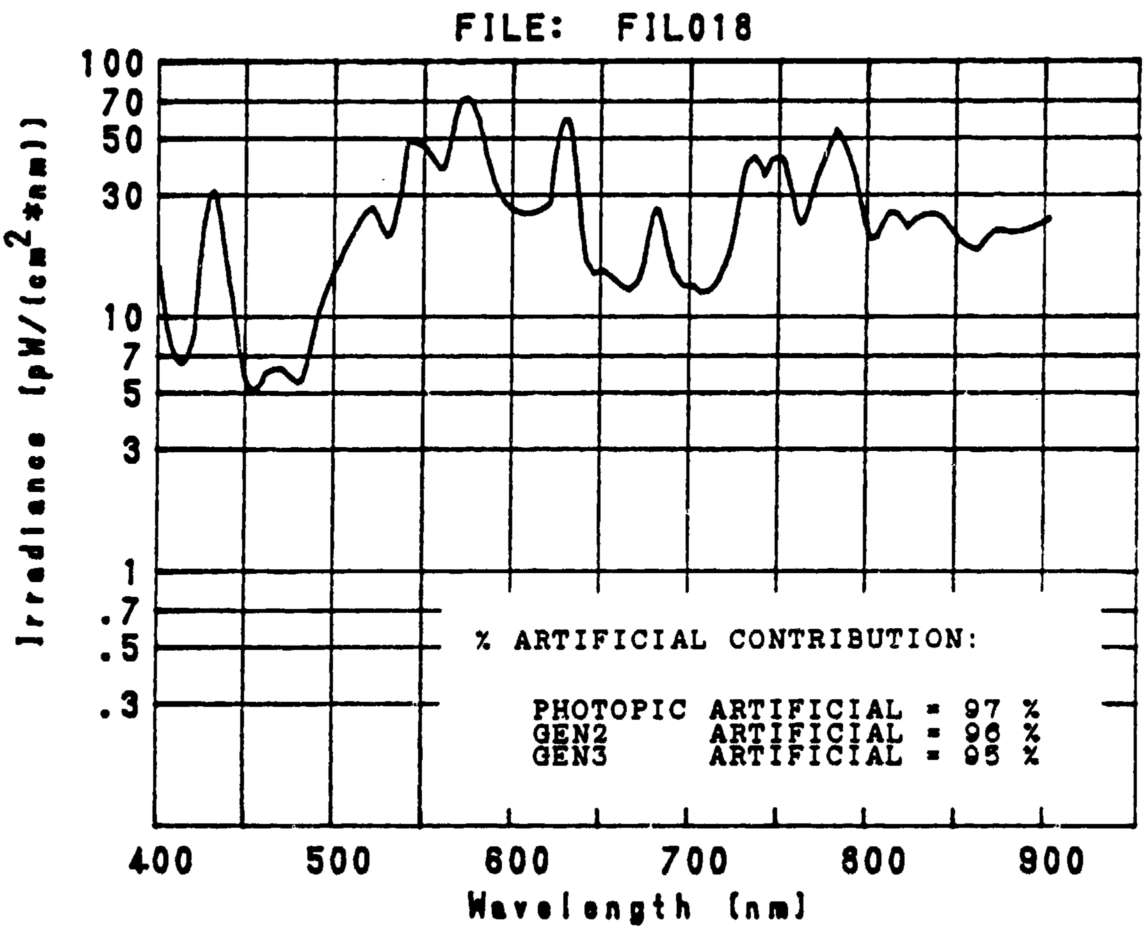
FOE AN/PVS-7(A,B)
FT. BENNING, GA

NIGHT SKY RADIOMETRIC DATA

DATE:	10-27-86
TIME:	2025
SITE:	SIMPSON
CLOUD COVER:	0
CLOUD ALT.(FT):	N/A
MOON INCLINATION(DEG):	N/A
MOON AZIMUTH(DEG):	N/A
MOON PHASE:	N/A
REF. PANEL AZIMUTH(DEG):	330
REF. PANEL INCL.(DEG):	45
REL. HUMIDITY (%):	71
TEMPERATURE (F):	56

RADIOMETRIC CALCULATED RESULTS:

PHOTOPIC = 2.47E-3 FC
GEN2 = 1.78E-3 HN2
GEN3 = 1.54E-3 HN3



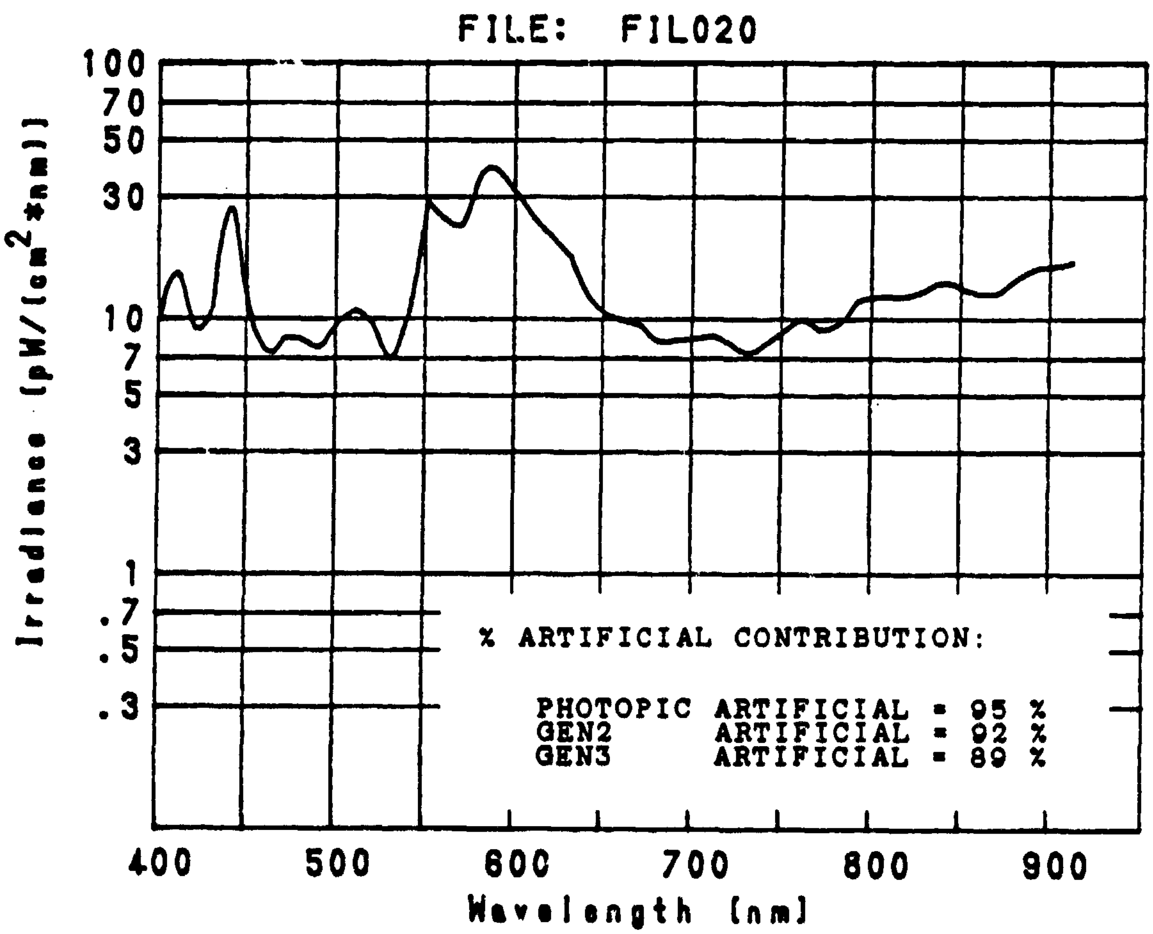
FOE AN/PVS-7(A,B)
FT. BENNING, GA

NIGHT SKY RADIOMETRIC DATA

DATE:	10-28-86
TIME:	1914
SITE:	SIMPSON
CLOUD COVER:	0
CLOUD ALT.(FT):	N/A
MOON INCLINATION(DEG):	N/A
MOON AZIMUTH(DEG):	N/A
MOON PHASE:	N/A
REF. PANEL AZIMUTH(DEG):	327
REF. PANEL INCL.(DEG):	45
REL. HUMIDITY (%):	59
TEMPERATURE (F):	62

RADIOMETRIC CALCULATED RESULTS:

PHOTOPIC = 1.40E-3 FC
GEN2 = 9.42E-4 HN2
GEN3 = 6.99E-4 HN3



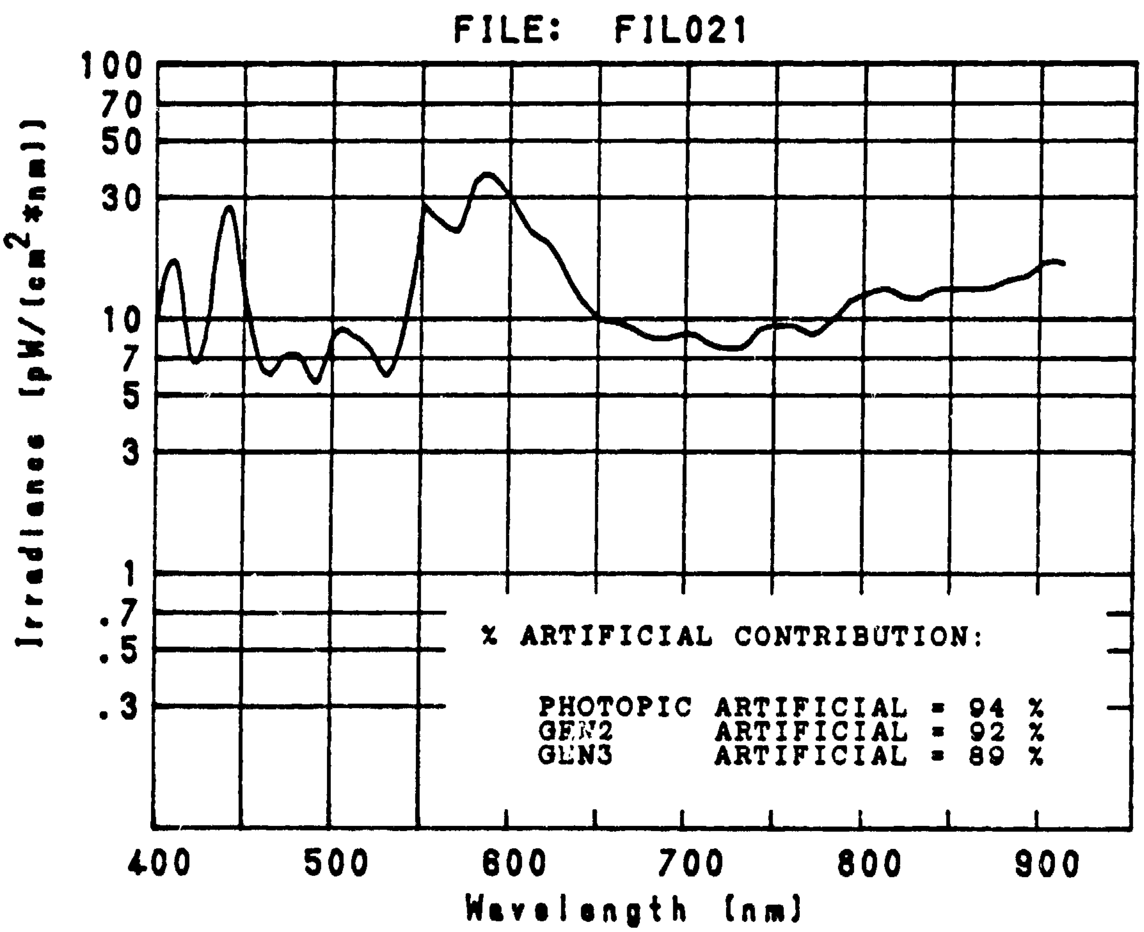
FOE AN/PVS-7(A,B)
FT. BENNING, GA

NIGHT SKY RADIOMETRIC DATA

DATE:	10-28-86
TIME:	2010
SITE:	SIMPSON
CLOUD COVER:	0
CLOUD ALT.(FT):	N/A
MOON INCLINATION(DEG):	N/A
MOON AZIMUTH(DEG):	N/A
MOON PHASE:	N/A
REF. PANEL AZIMUTH(DEG):	327
REF. PANEL INCL.(DEG):	45
REL. HUMIDITY (%):	71
TEMPERATURE (F):	55

RADIOMETRIC CALCULATED RESULTS:

PHOTOPIC = 1.30E-3 FC
GEN2 = 8.92E-4 HN2
GEN3 = 6.79E-4 HN3



FOE AN/PVS-7(A,B)
FT. BENNING, GA

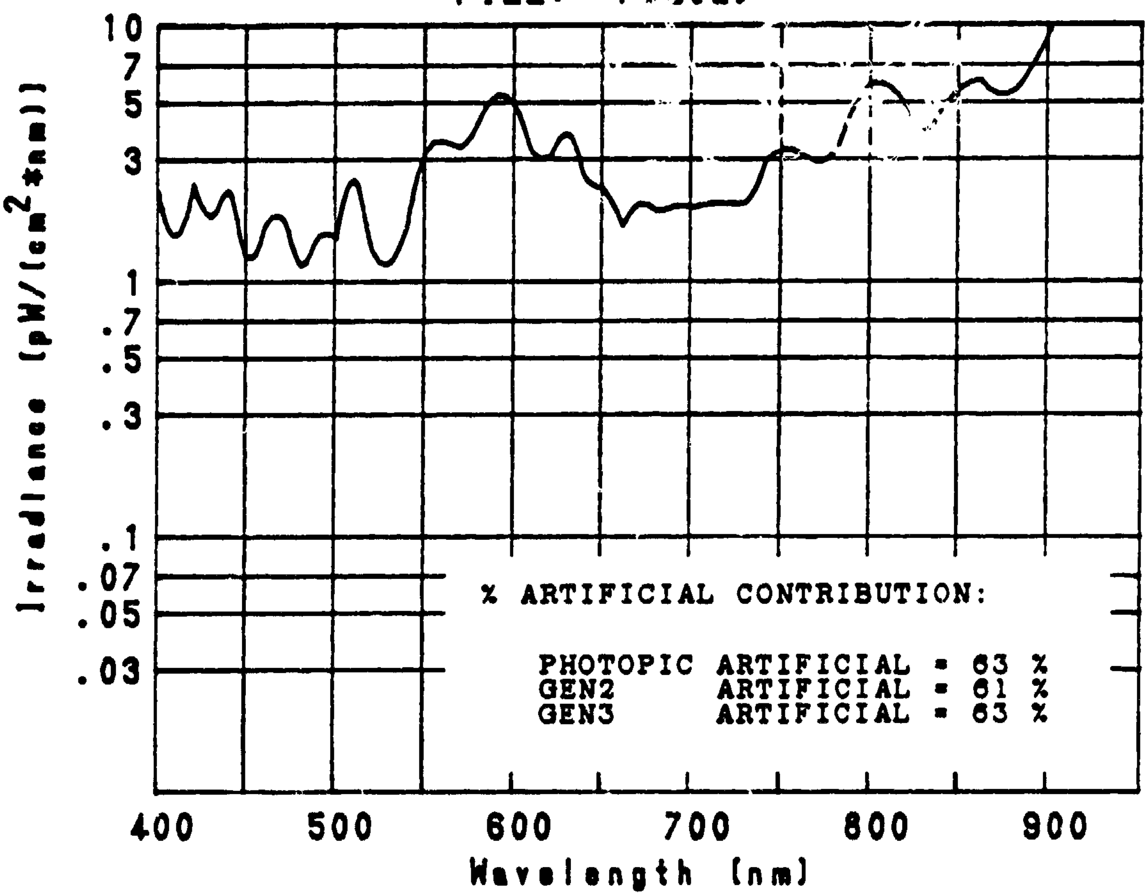
NIGHT SKY RADIOMETRIC DATA

DATE:	10-30-86
TIME:	1857
SITE:	GRISWOLD;BH
CLOUD COVER:	0
CLOUD ALT.(FT):	N/A
MOON INCLINATION(DEG):	N/A
MOON AZIMUTH(DEG):	N/A
MOON PHASE:	N/A
REF. PANEL AZIMUTH(DEG):	180
REF. PANEL INCL.(DEG):	45
REL. HUMIDITY (%):	68
TEMPERATURE (F):	60

RADIOMETRIC CALCULATED RESULTS:

PHOTOPIC = 2.00E-4 FC
GEN2 = 1.6[illegible]E-4 HN2
GEN3 = 1.[illegible]-4 HN3

FILE: FIL022



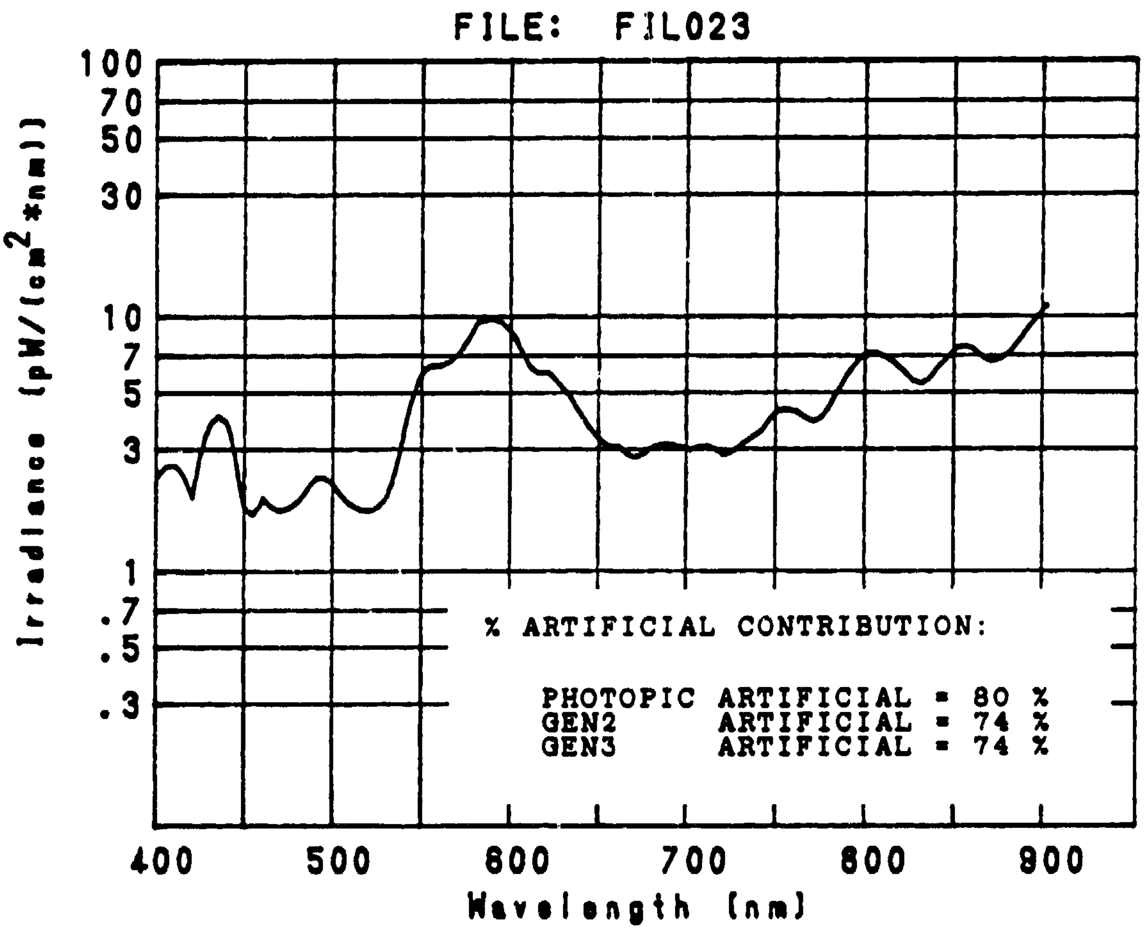
FOE AN/PVS-7 (A, B)
FT. BENNING, GA

NIGHT SKY RADIOMETRIC DATA

DATE:	10-30-86
TIME:	2005
SITE:	GRISWOLD:BH
CLOUD COVER:	0
CLOUD ALT. (FT):	N/A
MOON INCLINATION(DEG):	N/A
MOON AZIMUTH(DEG):	N/A
MOON PHASE:	N/A
REF. PANEL AZIMUTH(DEG):	350
REF. PANEL INCL. (DEG):	45
REL. HUMIDITY (%):	67
TEMPERATURE (F):	55

RADIOMETRIC CALCULATED RESULTS:

PHOTOPIC = 3.61E-4 FC
GEN2 = 2.89E-4 HN2
GEN3 = 2.79E-4 HN3



FOE AN/PVS-7(A,B)
FT. BENNING, GA

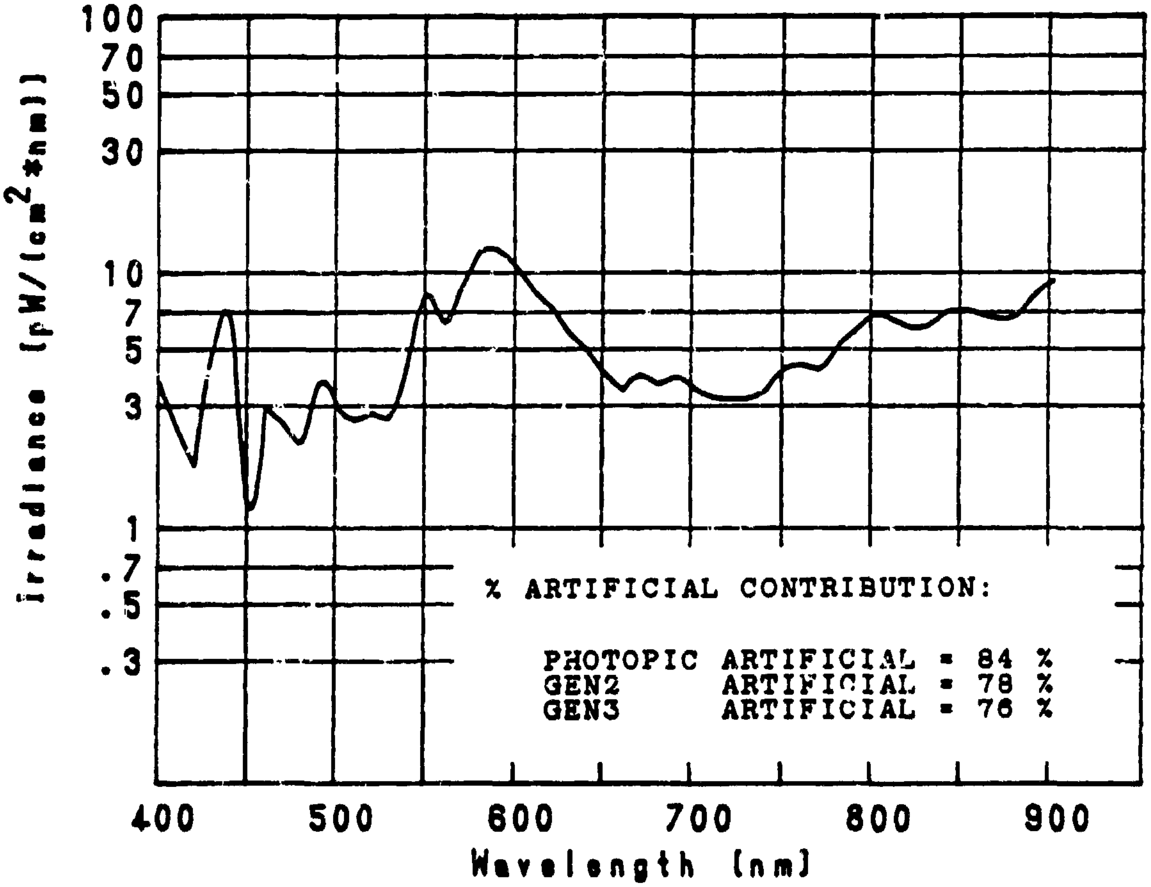
NIGHT SKY RADIOMETRIC DATA

DATE:	11-3-86
TIME:	1840
SITE:	GRISWOLD
CLOUD COVER:	SCT SCT
CLOUD ALT.(FT):	25K 35K
MOON INCLINATION(DEG):	N/A
MOON AZIMUTH(DEG):	N/A
MOON PHASE:	N/A
REF. PANEL AZIMUTH(DEG):	50
REF. PANEL INCL.(DEG):	45
REL. HUMIDITY (%):	75
TEMPERATURE (F):	66

RADIOMETRIC CALCULATED RESULTS:

PHOTOPIC = 4.58E-4 FC
GEN2 = 3.42E-4 HN2
GEN3 = 3.03E-4 HN3

FILE: FIL024



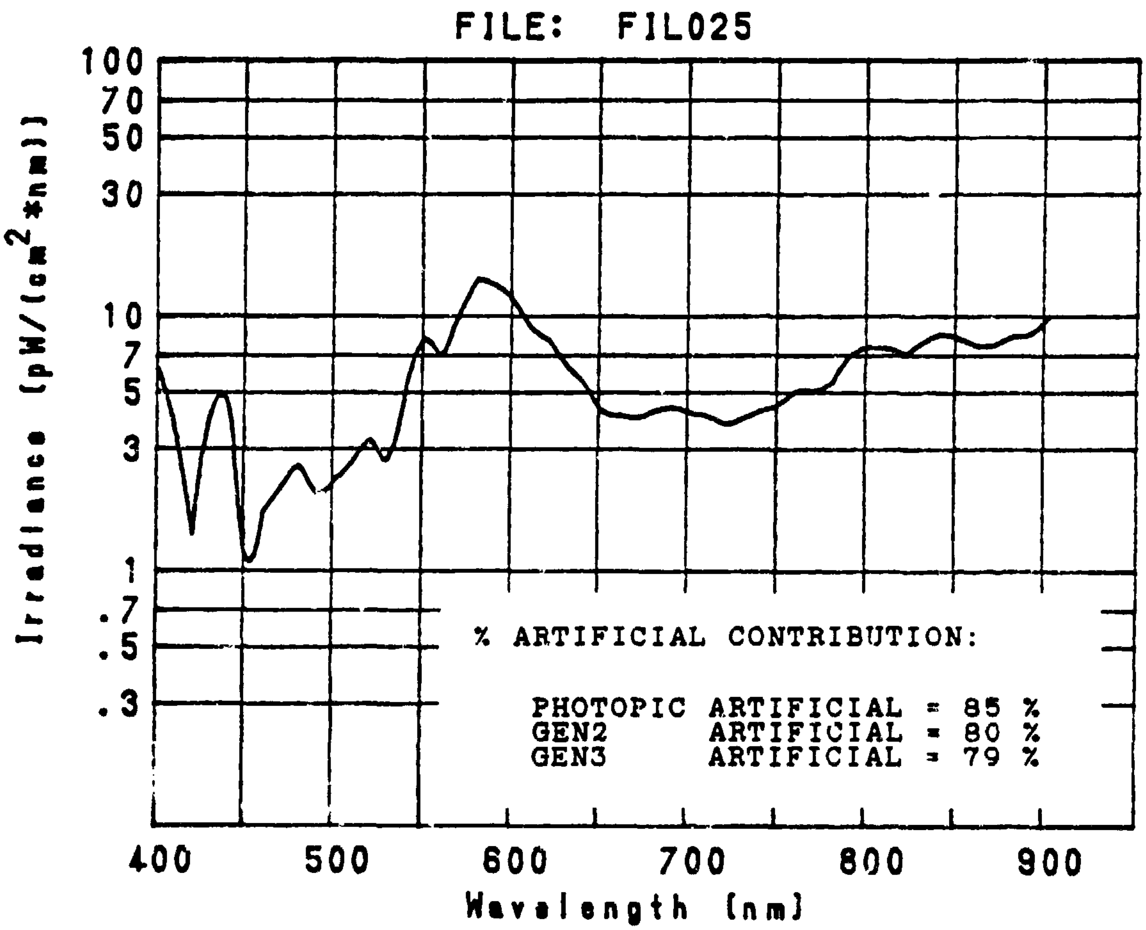
FOE AN/PVS-7(A,B)
FT. BENNING, GA

NIGHT SKY RADIOMETRIC DATA

DATE:	11-3-86
TIME:	1940
SITE:	GRISWOLD
CLOUD COVER:	SCT
CLOUD ALT.(FT):	7K
MOON INCLINATION(DEG):	N/A
MOON AZIMUTH(DEG):	N/A
MOON PHASE:	N/A
REF. PANEL AZIMUTH(DEG):	50
REF. PANEL INCL.(DEG):	45
REL. HUMIDITY (%):	75
TEMPERATURE (F):	66

RADIOMETRIC CALCULATED RESULTS:

PHOTOPIC = 4.90E-4 FC
GEN2 = 3.70E-4 HN2
GEN3 = 3.46E-4 HN3



FOE AN/PVS-7(A,B)
FT. BENNING, GA

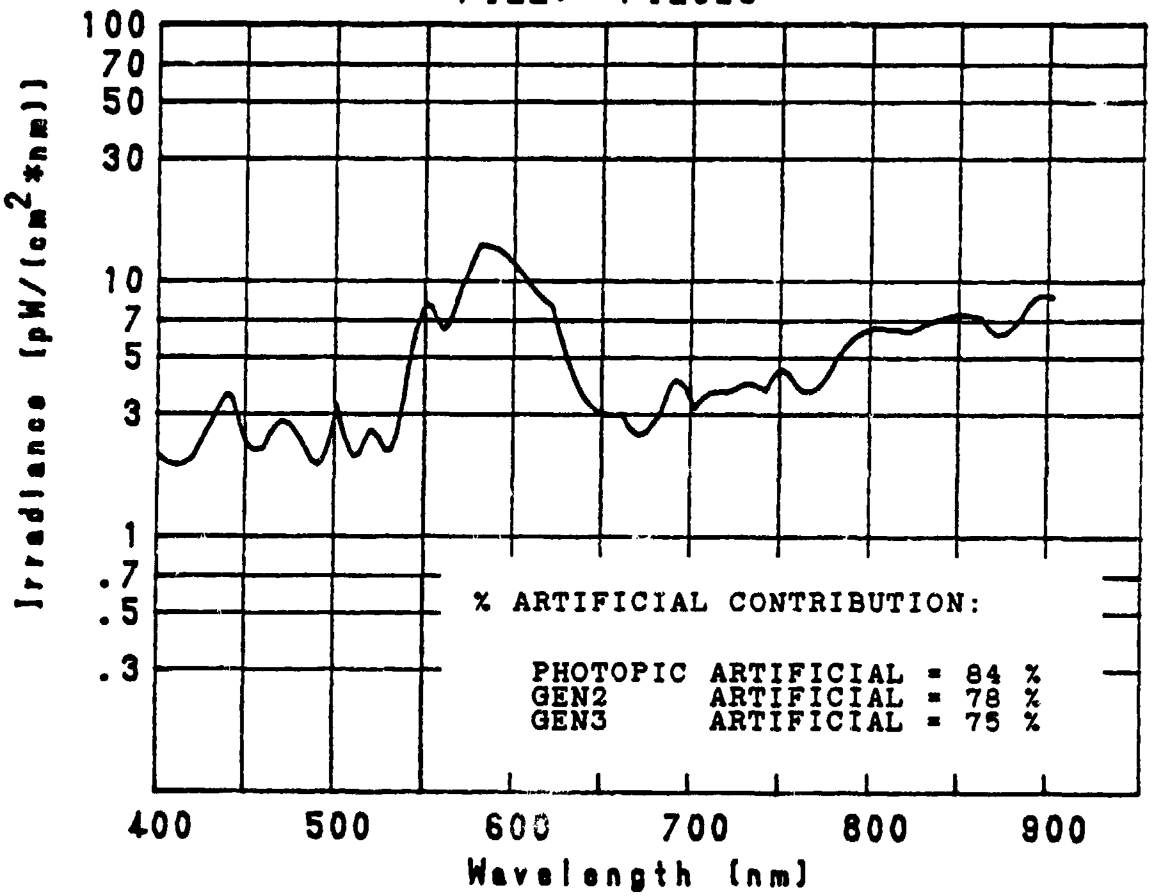
NIGHT SKY RADIOMETRIC DATA

DATE:	11-3-88
TIME:	2010
SITE:	GRISWOLD
CLOUD COVER:	SCT
CLOUD ALT. (FT):	7K
MOON INCLINATION(DEG):	N/A
MOON AZIMUTH(DEG):	N/A
MOON PHASE:	N/A
REF. PANEL AZIMUTH(DEG):	50
REF. PANEL INCL. (DEG):	45
REL. HUMIDITY (%):	[illegible]4
TEMPERATURE (F):	62

RADIOMETRIC CALCULATED RESULTS:

PHOTOPIC = 4.66E-4 FC
GEN2 = 3.33E-4 HN2
GEN3 = 3.00E-4 HN3

FILE: FIL026



FOE AN/PVS-7(A,B)
FT. BENNING, GA

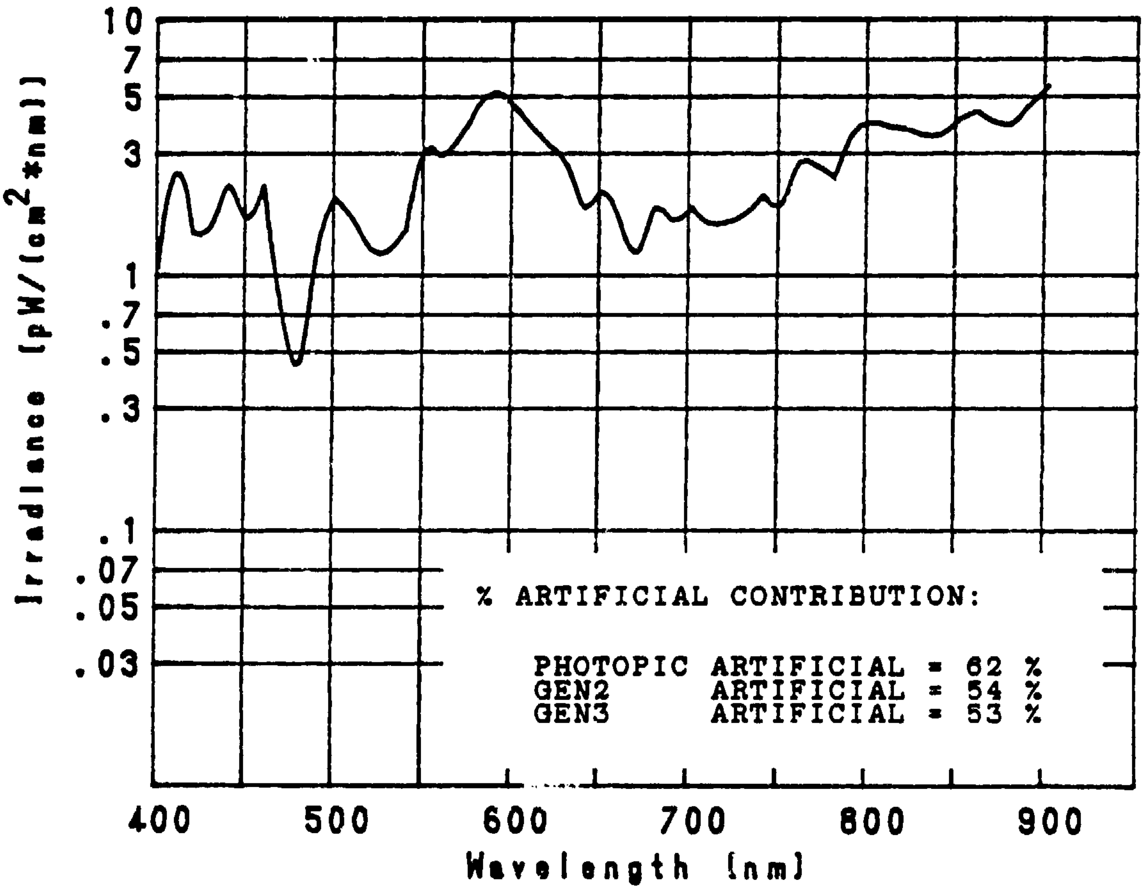
NIGHT SKY RADIOMETRIC DATA

DATE:	11-3-86
TIME:	2145
SITE:	GRISWOLD
CLOUD COVER:	SCT
CLOUD ALT. (FT):	7K
MOON INCLINATION(DEG):	N/A
MOON AZIMUTH(DEG):	N/A
MOON PHASE:	N/A
REF. PANEL AZIMUTH(DEG):	150
REF. PANEL INCL. (DEG):	45
REL. HUMIDITY (%):	78
TEMPERATURE (F):	58

RADIOMETRIC CALCULATED RESULTS:

PHOTOPIC = 1.92E-4 FC
GEN2 = 1.62E-4 HN2
GEN3 = 1.57E-4 HN3

FILE: FIL027



FOE AN/PVS-7(A,B)
FT. BENNING, GA

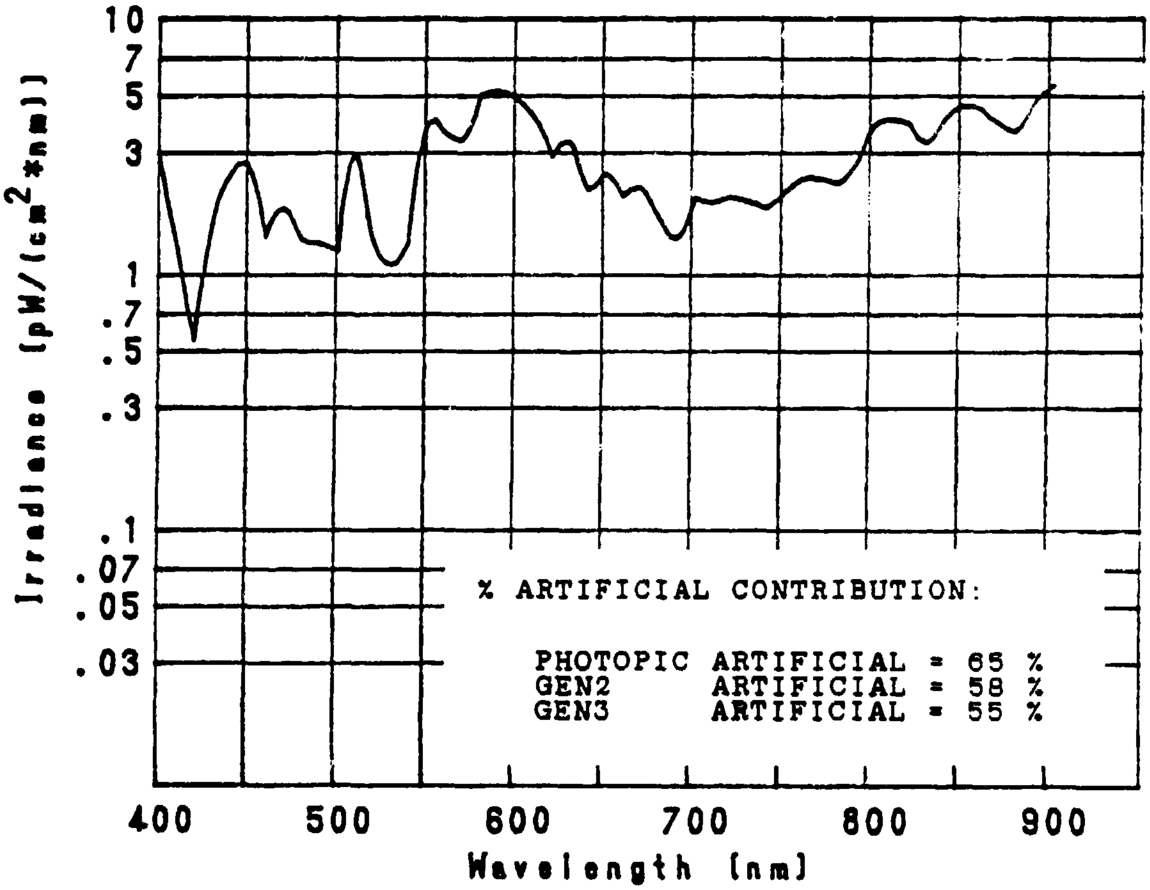
NIGHT SKY RADIOMETRIC DATA

DATE:	11-3-86
TIME:	2230
SITE:	GRISWOLD
CLOUD COVER:	SCT
CLOUD ALT. (FT):	7K
MOON INCLINATION(DEG):	N/A
MOON AZIMUTH(DEG):	N/A
MOON PHASE:	N/A
REF. PANEL AZIMUTH(DEG):	150
REF. PANEL INCL. (DEG):	45
REL. HUMIDITY (%):	78
TEMPERATURE (F):	58

RADIOMETRIC CALCULATED RESULTS:

PHOTOPIC = 2.10E-4 FC
GEN2 = 1.74E-4 HN2
GEN3 = 1.62E-4 HN3

FILE: FIL028



FOE AN/PVS-7(A,B)
FT. BENNING, GA

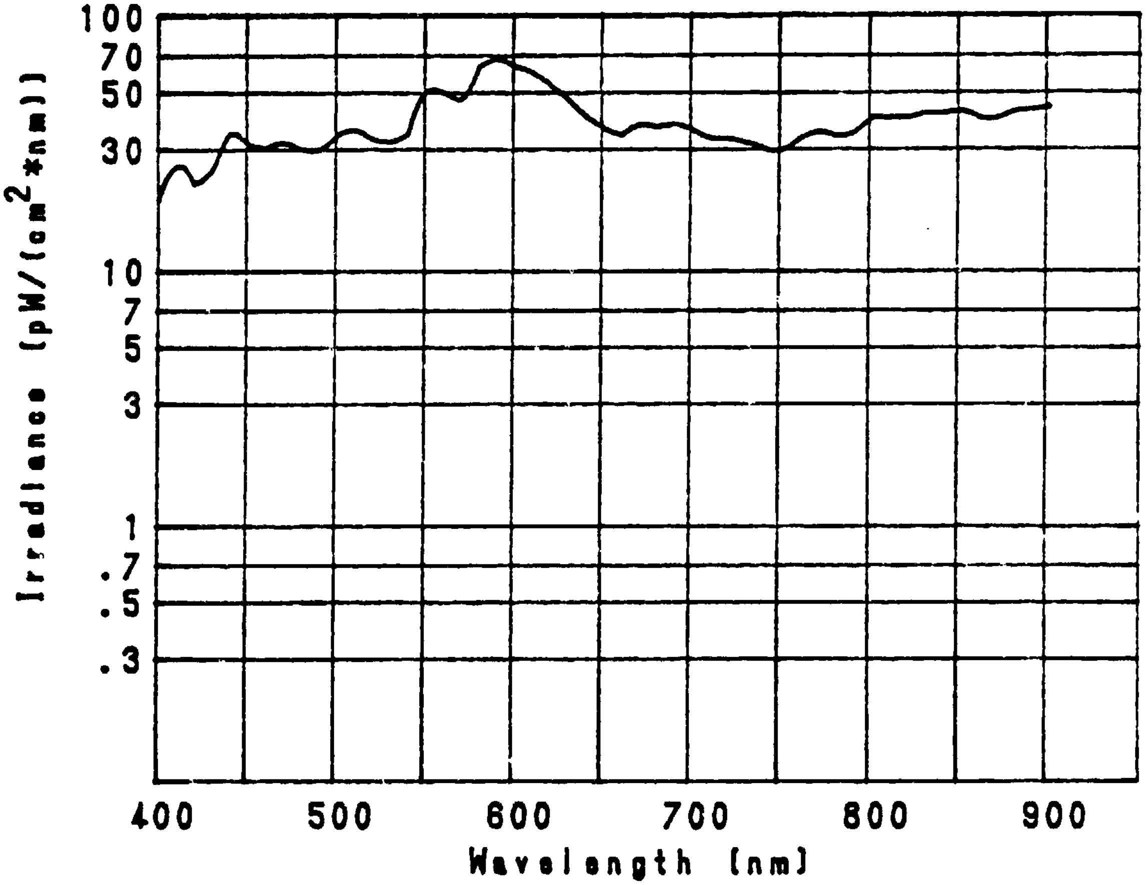
NIGHT SKY RADIOMETRIC DATA

DATE:	11-10-86
TIME:	1900
SITE:	LAE FIELD
CLOUD COVER:	SKT BKN
CLOUD ALT.(FT):	10K 25K
MOON INCLINATION(DEG):	55
MOON AZIMUTH(DEG):	150
MOON PHASE:	67%WAX
REF. PANEL AZIMUTH(DEG):	0
REF. PANEL INCL.(DEG):	45
REL. HUMIDITY (%):	34
TEMPERATURE (F):	75

RADIOMETRIC CALCULATED RESULTS:

PHOTOPIC = 3.14E-3 FC
GEN2 = 2.61E-3 HN2
GEN3 = 2.23E-3 HN3

FILE: FIL036



FOE AN/PVS-7(A,B)
FT. BENNING, GA

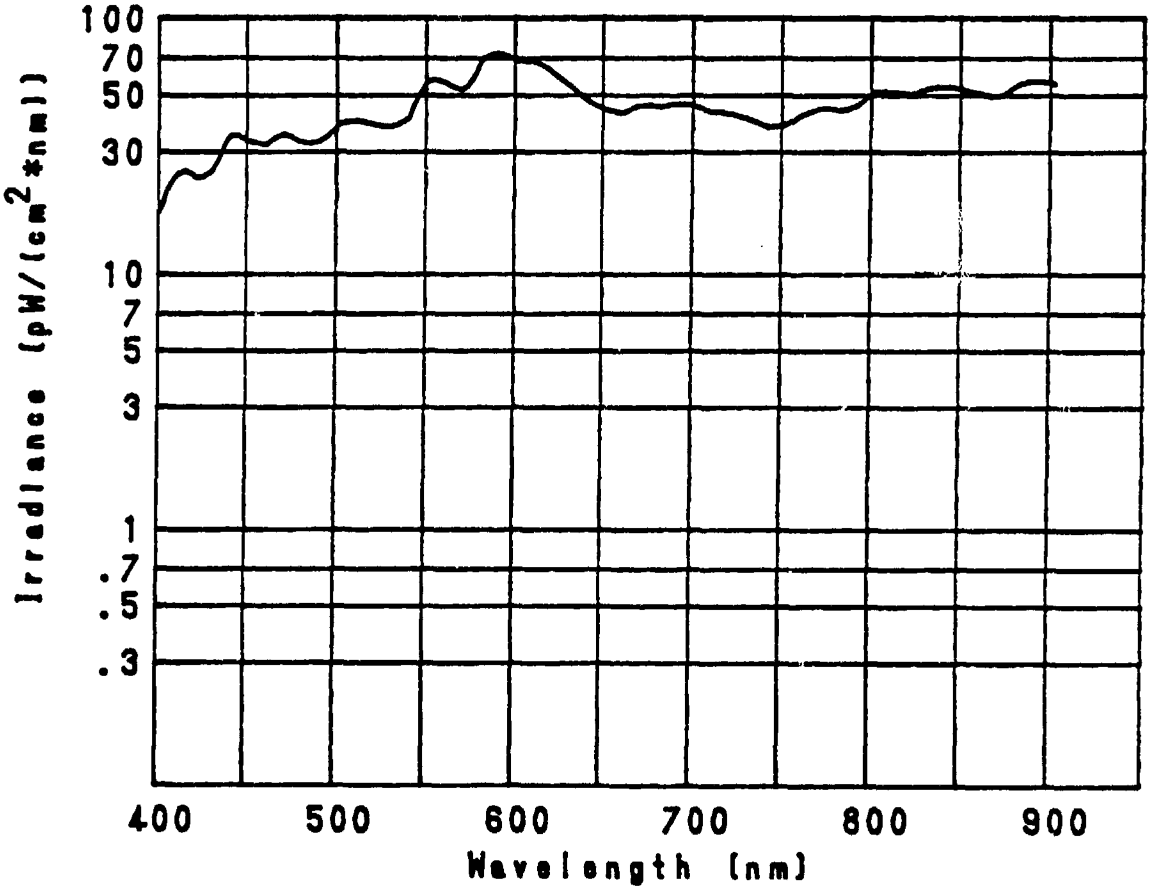
NIGHT SKY RADIOMETRIC DATA

DATE:	11-10-86
TIME:	2015
SITE:	LAE FIELD
CLOUD COVER:	OVC
CLOUD ALT.(FT):	10K
MOON INCLINATION(DEG):	55
MOON AZIMUTH(DEG):	150
MOON PHASE:	67%MAX
REF. PANEL AZIMUTH(DEG):	0
REF. PANEL INCL.(DEG):	45
REL. HUMIDITY (%):	34
TEMPERATURE (F):	75

RADIOMETRIC CALCULATED RESULTS:

PHOTOPIC = 3.52E-3 FC
GEN2 = 3.06E-3 HN2
GEN3 = 2.77E-3 HN3

FILE: FIL037



FOE AN/PVS-7(A,B)
FT. BENNING, GA

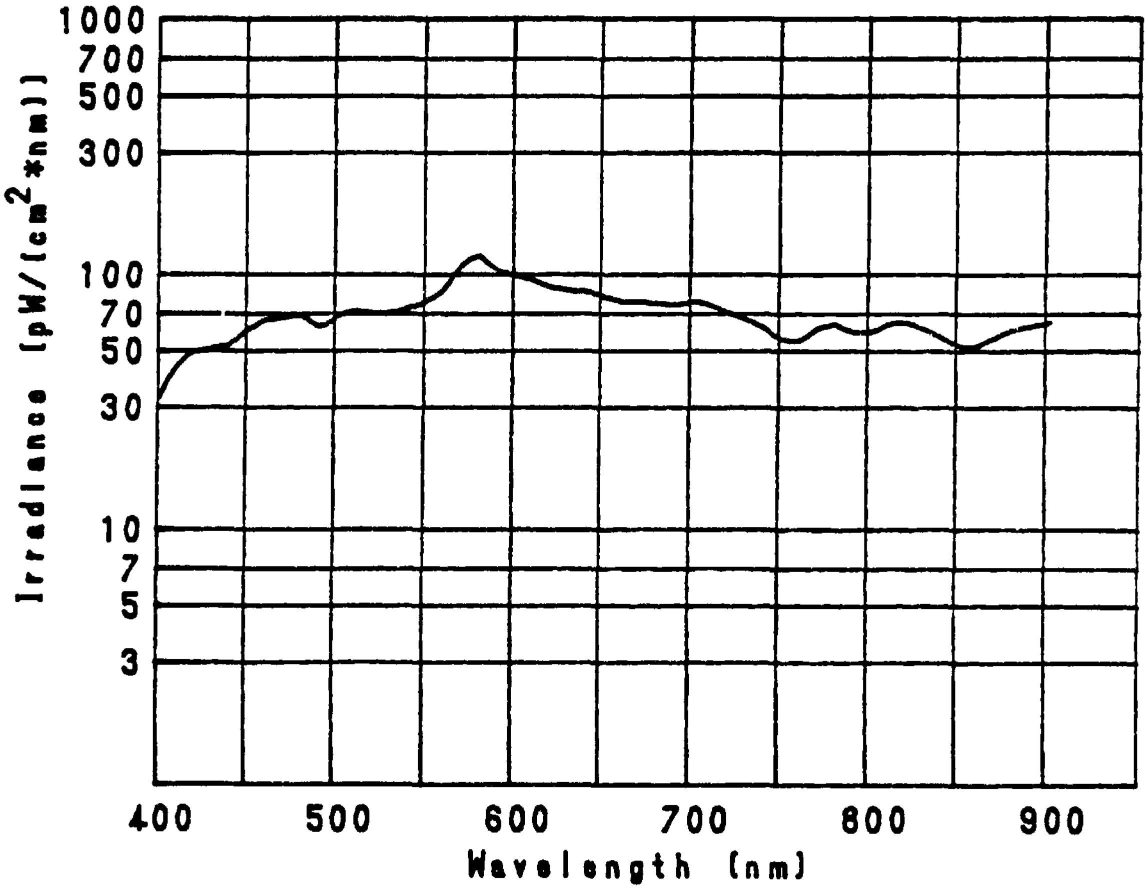
NIGHT SKY RADIOMETRIC DATA

DATE:	11-11-86
TIME:	2030
SITE:	LAE FIELD
CLOUD COVER:	BKN BKN OVC
CLOUD ALT.(FT):	4K 10K 25K
MOON INCLINATION(DEG):	55
MOON AZIMUTH(DEG):	200
MOON PHASE:	76%MAX
REF. PANEL AZIMUTH(DEG):	160
REF. PANEL INCL.(DEG):	45
REL. HUMIDITY (%):	77
TEMPERATURE (F):	77

RADIOMETRIC CALCULATED RESULTS:

PHOTOPIC = 5.81E-3 FC
GEN2 = 4.90E-3 HN2
GEN3 = 4.01E-3 HN3

FILE: FIL040



FOE AN/PVS-7(A,B)
FT. BENNING, GA

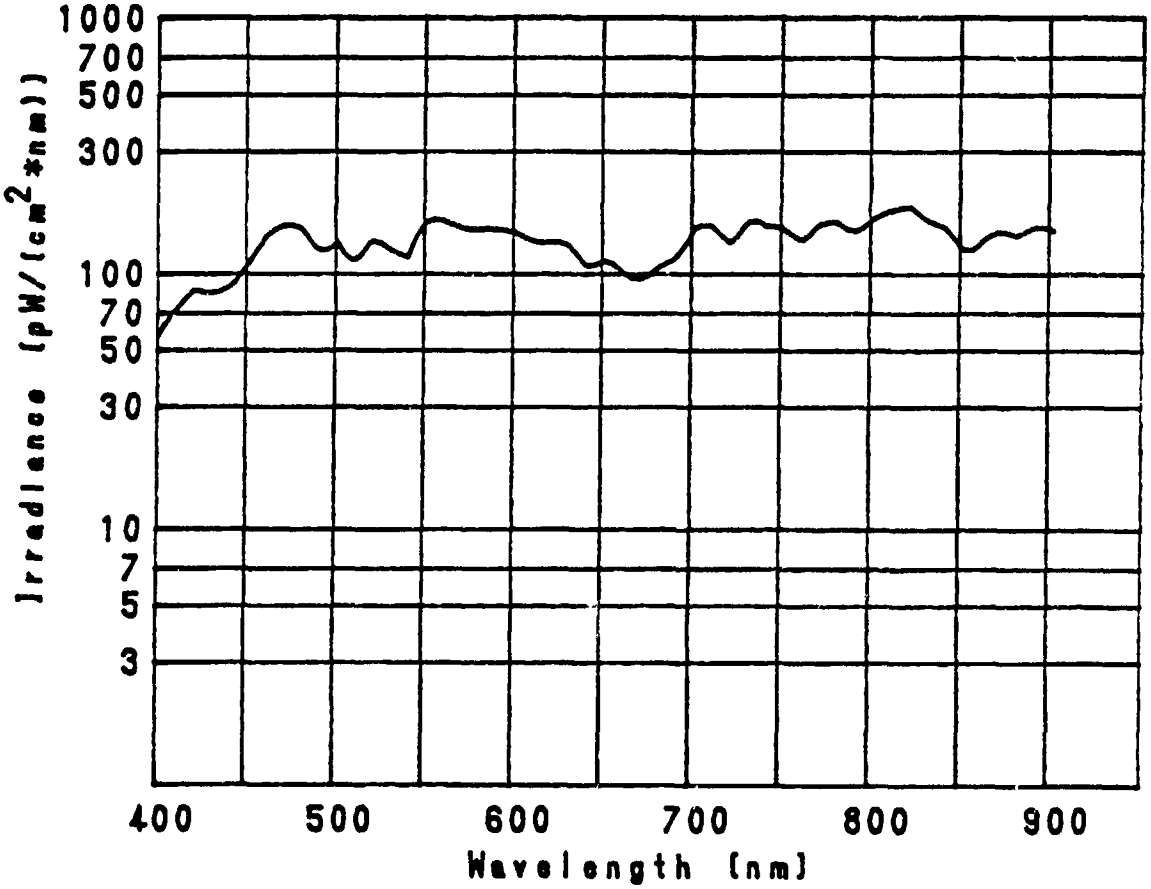
NIGHT SKY RADIOMETRIC DATA

DATE:	11-11-86
TIME:	2100
SITE:	LAE FIELD
CLOUD COVER:	SCT SCT BKN
CLOUD ALT.(FT):	4K 10K 25K
MOON INCLINATION(DEG):	60
MOON AZIMUTH(DEG):	200
MOON PHASE:	76%MAX
REF. PANEL AZIMUTH(DEG):	160
REF. PANEL INCL.(DEG):	45
REL. HUMIDITY (%):	77
TEMPERATURE (F):	77

RADIOMETRIC CALCULATED RESULTS:

PHOTOPIC = 9.29E-3 FC
GEN2 = 8.88E-3 HN2
GEN3 = 8.02E-3 HN3

FILE: FIL041



FOE AN/PVS-7 (A, B)
FT. BENNING, GA

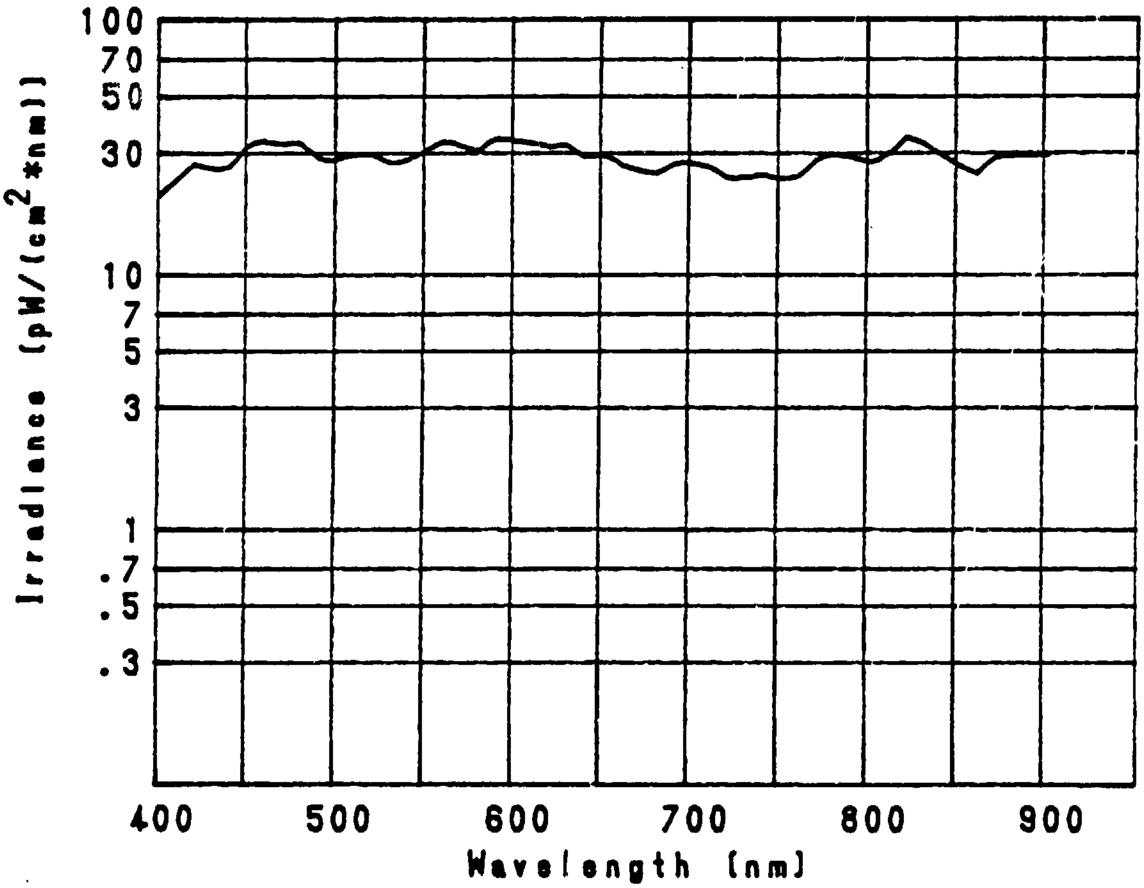
NIGHT SKY RADIOMETRIC DATA

DATE:	11-12-86
TIME:	1934
SITE:	LAE FIELD
CLOUD COVER:	BKN BKN
CLOUD ALT. (FT):	2K 25K
MOON INCLINATION(DEG):	55
MOON AZIMUTH(DEG):	120
MOON PHASE:	84%MAX
REF. PANEL AZIMUTH(DEG):	0
REF. PANEL INCL. (DEG):	45
REL. HUMIDITY (%):	71
TEMPERATURE (F):	65

RADIOMETRIC CALCULATED RESULTS:

PHOTOPIC = 2.07E-3 FC
GEN2 = 1.92E-3 HN2
GEN3 = 1.61E-3 HN3

FILE: FIL043



FOE AN/PVS-7(A,B)
FT. BENNING, GA

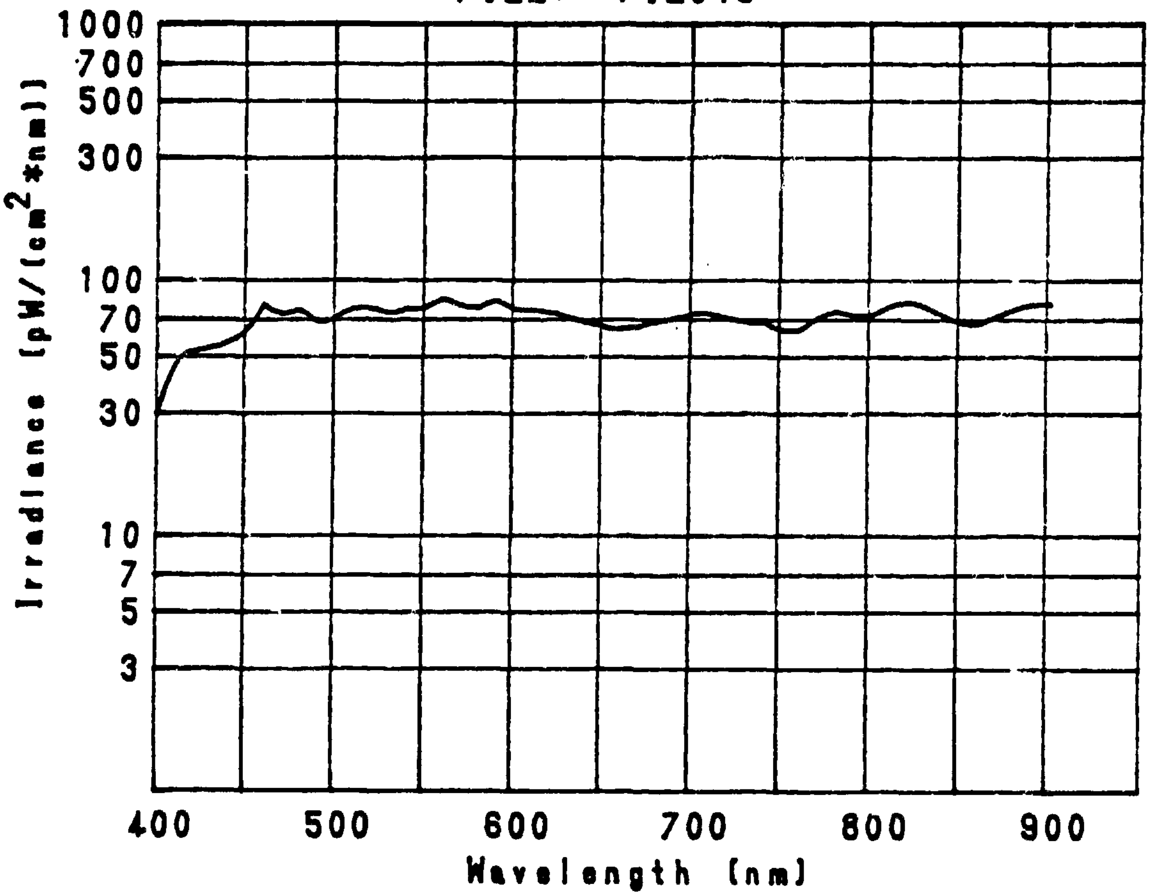
NIGHT SKY RADIOMETRIC DATA

DATE:	11-12-86
TIME:	2200
SITE:	LAE FIELD
CLOUD COVER:	OVC
CLOUD ALT.(FT):	1.5K
MOON INCLINATION(DEG):	65
MOON AZIMUTH(DEG):	160
MOON PHASE:	84%WAX
REF. PANEL AZIMUTH(DEG):	180
REF. PANEL INCL.(DEG):	45
REL. HUMIDITY (%):	71
TEMPERATURE (F):	65

RADIOMETRIC CALCULATED RESULTS:

PHOTOPIC = 5.16E-3 FC
GEN2 = 4.76E-3 HN2
GEN3 = 4.09E-3 HN3

FILE: FIL045



FOE AN/PVS-7(A,B)
FT. BENNING, GA

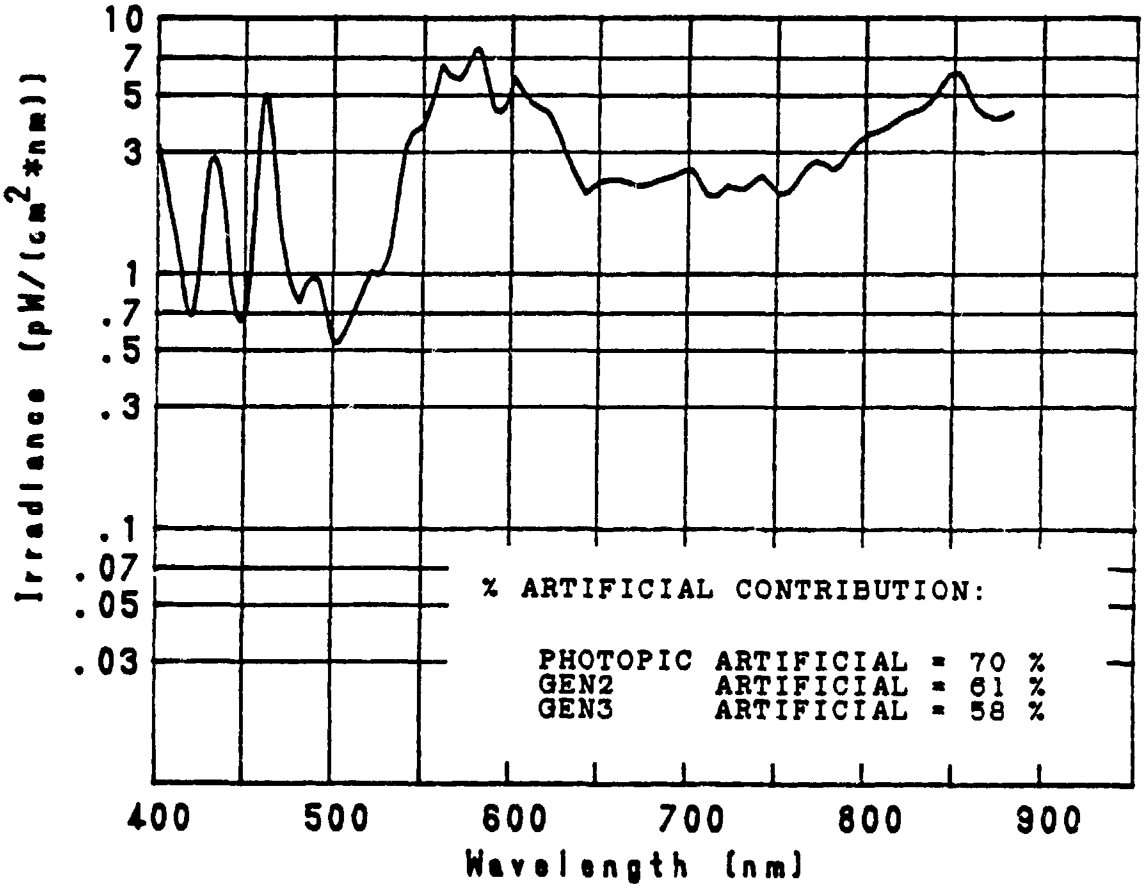
NIGHT SKY RADIOMETRIC DATA

DATE:	12-2-88
TIME:	1912
SITE:	GRISWOLD:BH
CLOUD COVER:	OVC
CLOUD ALT.(FT):	1.2K
MOON INCLINATION(DEG):	N/A
MOON AZIMUTH(DEG):	N/A
MOON PHASE:	N/A
REF. PANEL AZIMUTH(DEG):	345
REF. PANEL INCL.(DEG):	60
REL. HUMIDITY (%):	87
TEMPERATURE (F):	54

RADIOMETRIC CALCULATED RESULTS:

PHOTOPIC = 2.47E-4 FC
GEN2 = 1.90E-4 HN2
GEN3 = 1.78E-4 HN3

FILE: FIL051



FOE AN/PVS-7(A,B)
FT. BENNING, GA

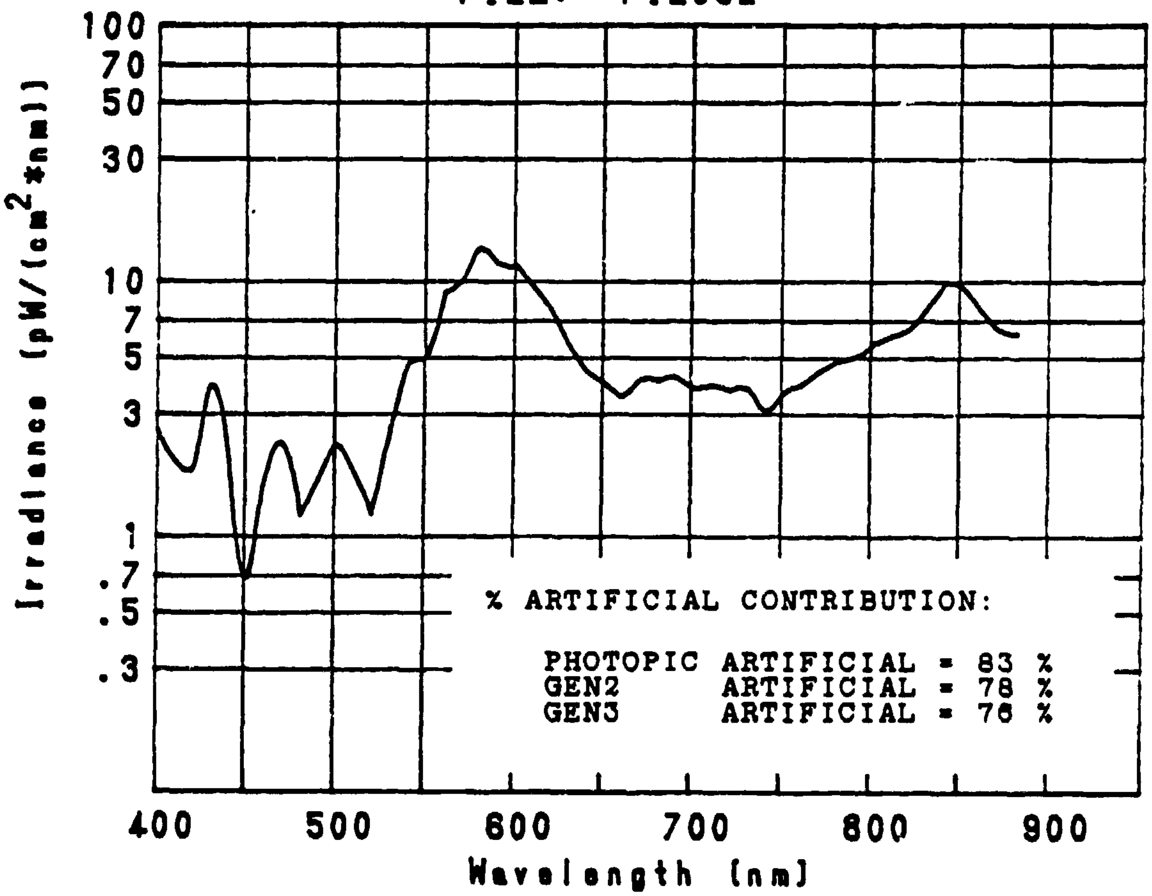
NIGHT SKY RADIOMETRIC DATA

DATE:	12-2-86
TIME:	2010
SITE:	GRISWOLD:BH
CLOUD COVER:	SCT SCT OVC
CLOUD ALT.(FT):	4K 7K 9K
MOON INCLINATION(DEG):	N/A
MOON AZIMUTH(DEG):	N/A
MOON PHASE:	N/A
REF. PANEL AZIMUTH(DEG):	345
REF. PANEL INCL.(DEG):	60
REL. HUMIDITY (%):	77
TEMPERATURE (F):	55

RADIOMETRIC CALCULATED RESULTS:

PHOTOPIC = 4.45E-4 FC
GEN2 = 3.30E-4 HN2
GEN3 = 3.10E-4 HN3

FILE: FIL052



FOE AN/PVS-7(A,B)
FT. BENNING, GA

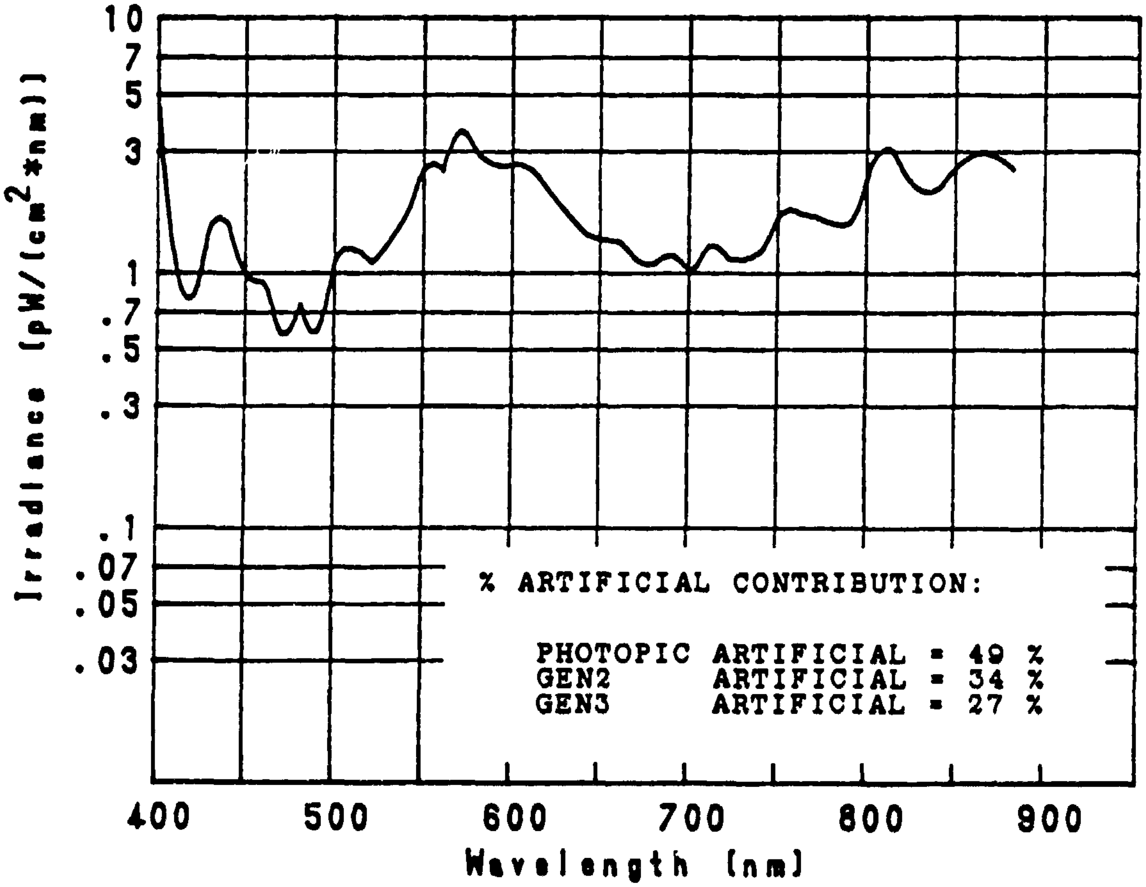
NIGHT SKY RADIOMETRIC DATA

DATE:	12-2-96
TIME:	2050
SITE:	GRISWOLD:BH
CLOUD COVER:	SCT
CLOUD ALT.(FT):	3K
MOON INCLINATION(DEG):	N/A
MOON AZIMUTH(DEG):	N/A
MOON PHASE:	N/A
REF. PANEL AZIMUTH(DEG):	200
REF. PANEL INCL.(DEG):	45
REL. HUMIDITY (%):	65
TEMPERATURE (F):	54

RADIOMETRIC CALCULATED RESULTS:

PHOTOPIC = 1.45E-4 FC
GEN2 = 1.12E-4 HN2
GEN3 = 1.01E-4 HN3

FILE: FIL053



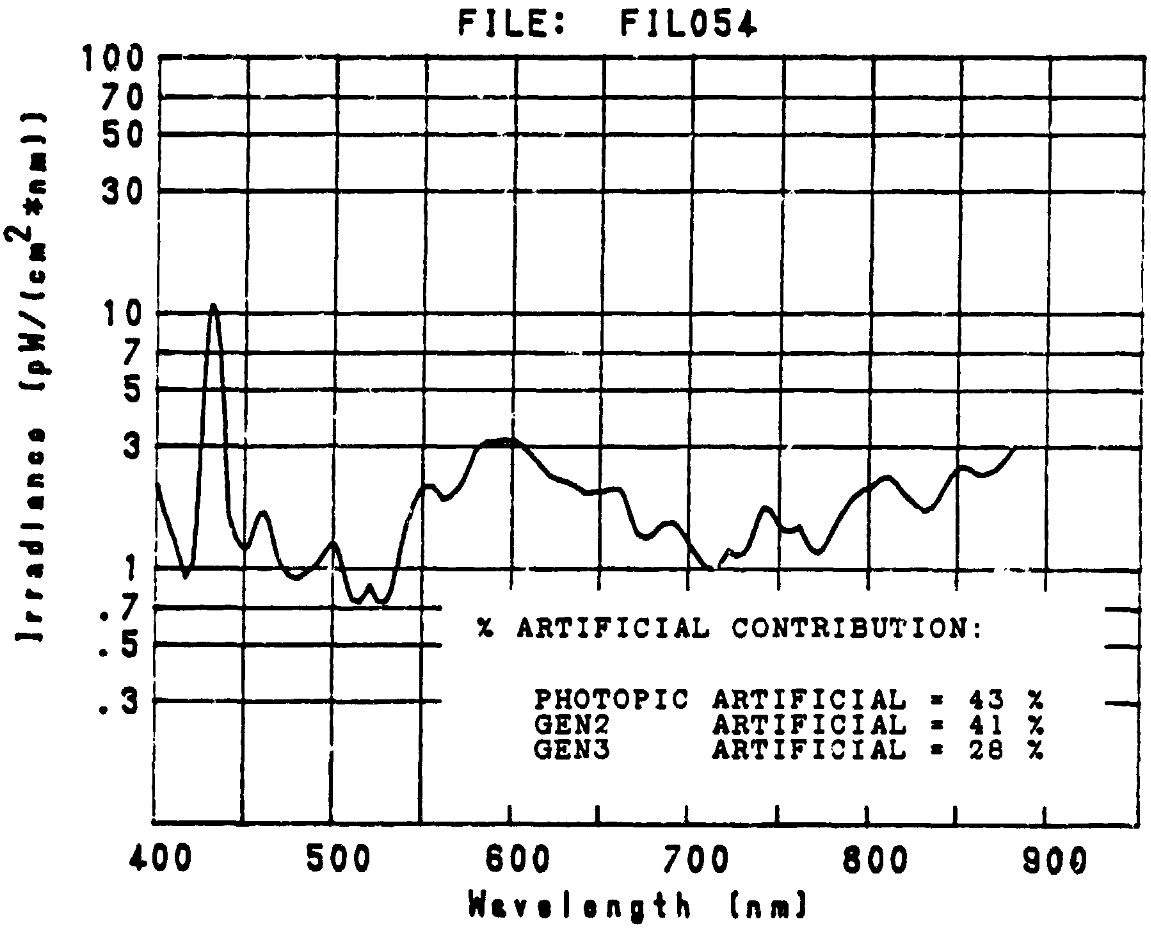
FOE AN/PVS-7 (A,B)
FT. BENNING, GA

NIGHT SKY RADIOMETRIC DATA

DATE:	12-2-86
TIME:	2125
SITE:	GRISWOLD:BH
CLOUD COVER:	CLR
CLOUD ALT. (FT):	N/A
MOON INCLINATION(DEG):	N/A
MOON AZIMUTH(DEG):	N/A
MOON PHASE:	N/A
REF. PANEL AZIMUTH(DEG):	345
REF. PANEL INCL. (DEG):	60
REL. HUMIDITY (%):	50
TEMPERATURE (F):	51

RADIOMETRIC CALCULATED RESULTS:

PHOTOPIC = 1.30E-4 FC
GEN2 = 1.25E-4 HN2
GEN3 = 1.02E-4 HN3



FT. BENNING, GA

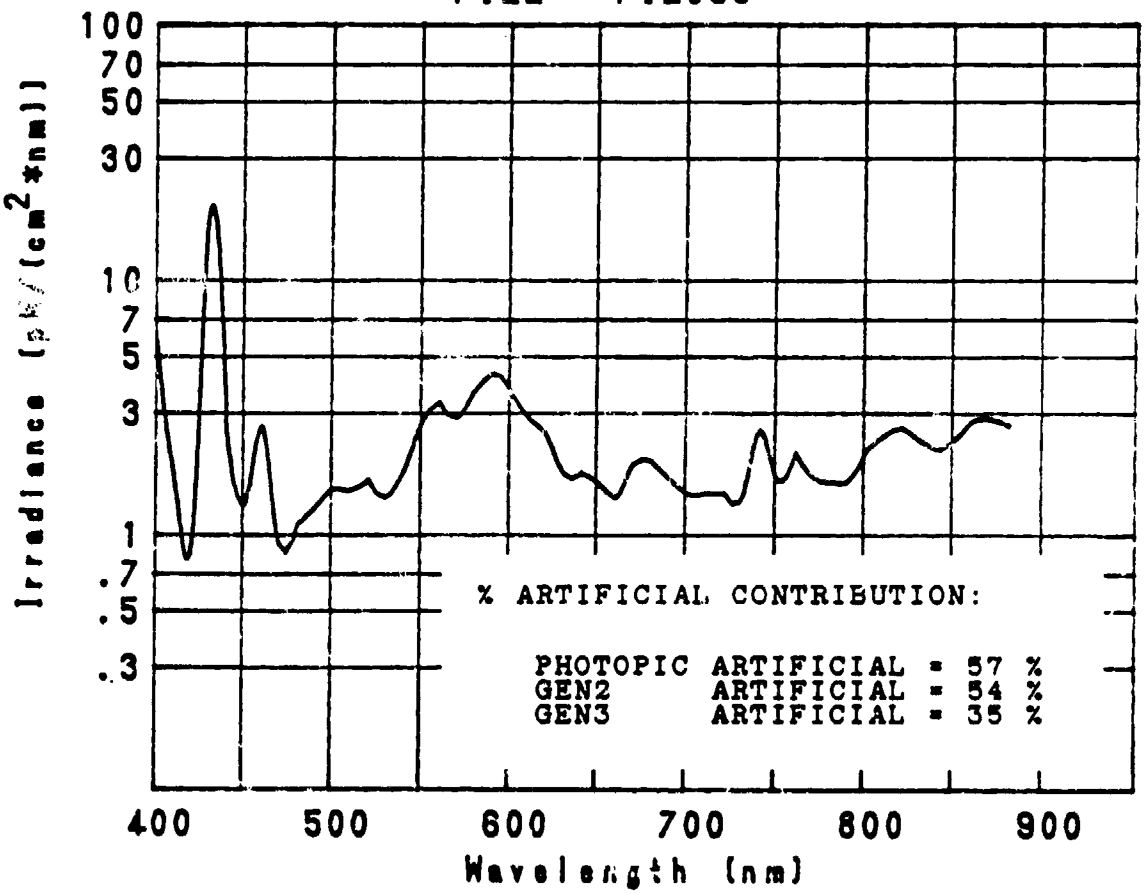
NIGHT SKY RADIOMETRIC DATA

DATE:	12-3-86
TIME:	1900
SITE:	GRISWOLD:BH
CLOUD COVER:	CLR
CLOUD ALT.(FT):	N/A
MOON INCLINATION(DEG):	5
MOON AZIMUTH(DEG):	230
MOON PHASE:	4%MAX
REF. PANEL AZIMUTH(DEG):	250
REF. PANEL INCL.(DEG):	45
REL. HUMIDITY (%):	63
TEMPERATURE (F):	45

RADIOMETRIC CALCULATED RESULTS:

PHOTOPIC = 1.71E-4 FC
GEN2 = 1.59E-4 HN2
GEN3 = 1.14E-4 HN3

FILE: FIL055



FOE AN/PVS-7(A,B)
FT. BENNING, GA

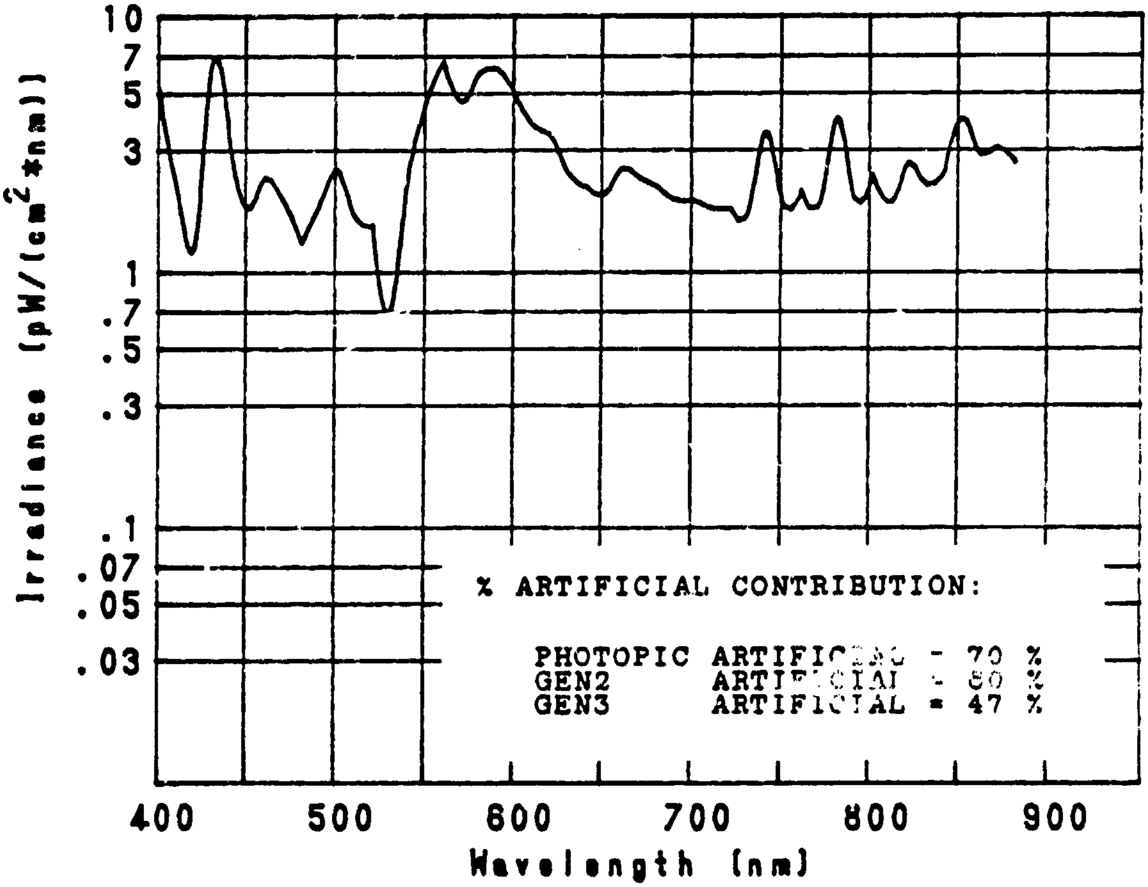
NIGHT SKY RADIOMETRIC DATA

DATE:	12-3-86
TIME:	1950
SITE:	GRISWOLD:BH
CLOUD COVER:	CLR
CLOUD ALT.(FT):	N/A
MOON INCLINATION(DEG):	N/A
MOON AZIMUTH(DEG):	N/A
MOON PHASE:	N/A
REF. PANEL AZIMUTH(DEG):	350
REF. PANEL INCL.(DEG):	60
REL. HUMIDITY (%):	60
TEMPERATURE (F):	40

RADIOMETRIC CALCULATED RESULTS:

PHOTOPIC = 2.45E-4 FC
GEN2 = 1.83E-4 HN2
GEN3 = 1.39E-4 HN3

FILE: FIL056



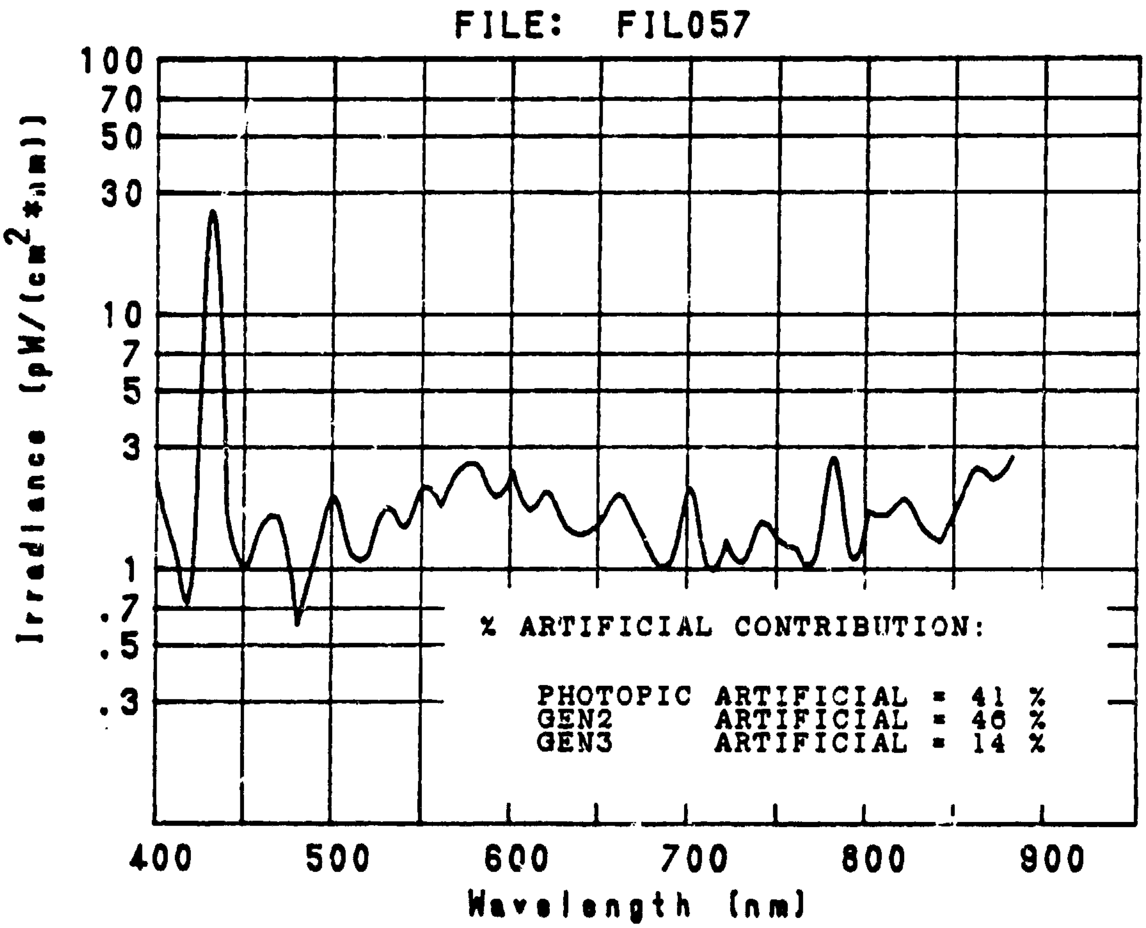
FOE AN/PVS-7(A,B)
FT. BENNING, GA

NIGHT SKY RADIOMETRIC DATA

DATE:	12-3-86
TIME:	2040
SITE:	GRISWOLD:BH
CLOUD COVER:	CLR
CLOUD ALT.(FT):	N/A
MOON INCLINATION(DEG):	N/A
MOON AZIMUTH(DEG):	N/A
MOON PHASE:	N/A
REF. PANEL AZIMUTH(DEG):	170
REF. PANEL INCL.(DEG):	30
REL. HUMIDITY (%):	56
TEMPERATURE (F):	38

RADIOMETRIC CALCULATED RESULTS:

PHOTOPIC = 1.25E-4 FC
GEN2 = 1.36E-4 HN2
GEN3 = 8.59E-5 HN3



APPENDIX I
HORIZON/CLOUD MEASUREMENTS

FOE AN/PVS-7(A,B)
FT. BENNING, GA

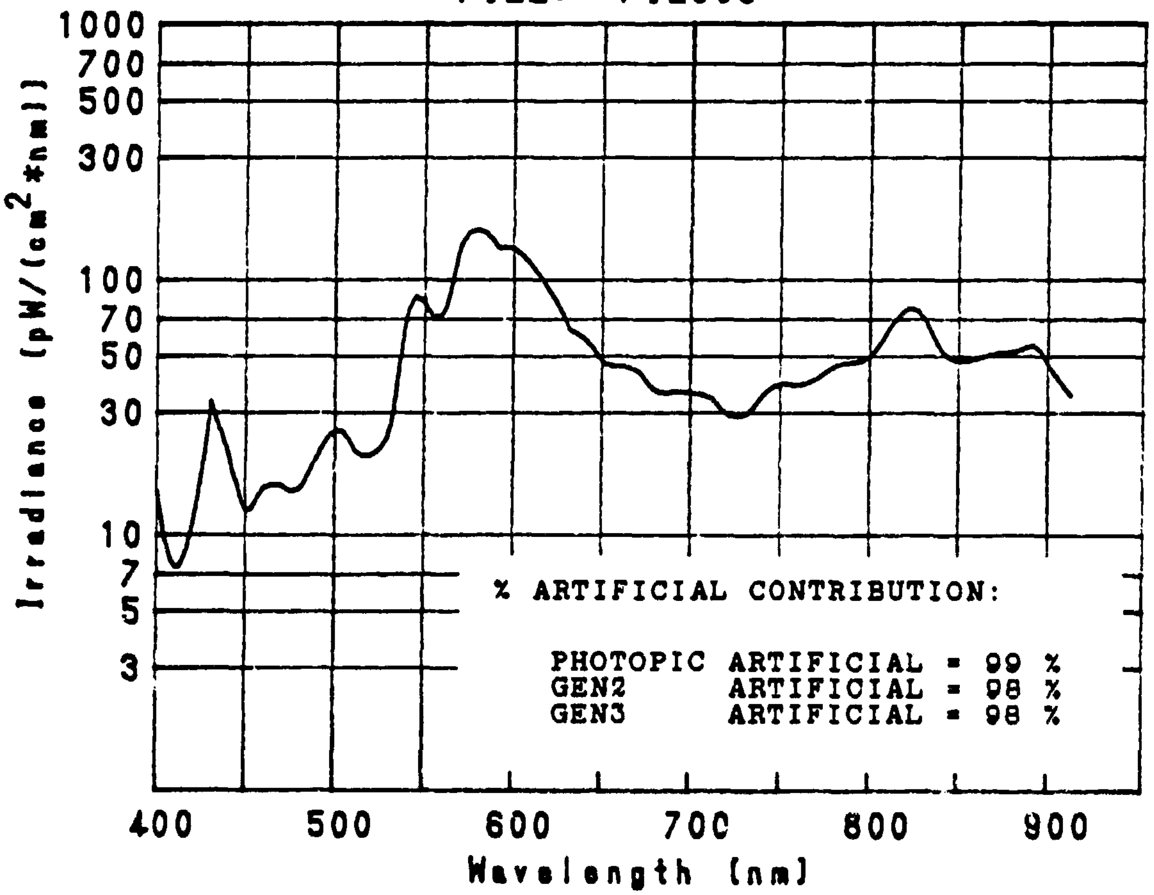
NIGHT SKY RADIOMETRIC DATA

DATE:	10-22-86
TIME:	2220
SITE:	GRISWOLD:BH
CLOUD COVER:	**HORIZON**
CLOUD ALT.(FT):	** MEAS. **
MOON INCLINATION(DEG):	N/A
MOON AZIMUTH(DEG):	N/A
MOON PHASE:	N/A
REF. PANEL AZIMUTH(DEG):	N/A
REF. PANEL INCL.(DEG):	N/A
REL. HUMIDITY (%):	70
TEMPERATURE (F):	53

RADIOMETRIC CALCULATED RESULTS:

PHOTOPIC = 5.42E-3 FC
GEN2 = 3.55E-3 HN2
GEN3 = 3.03E-3 HN3

FILE: FIL008



FOE AN/PVS-7(A,B)
FT. BENNING, GA

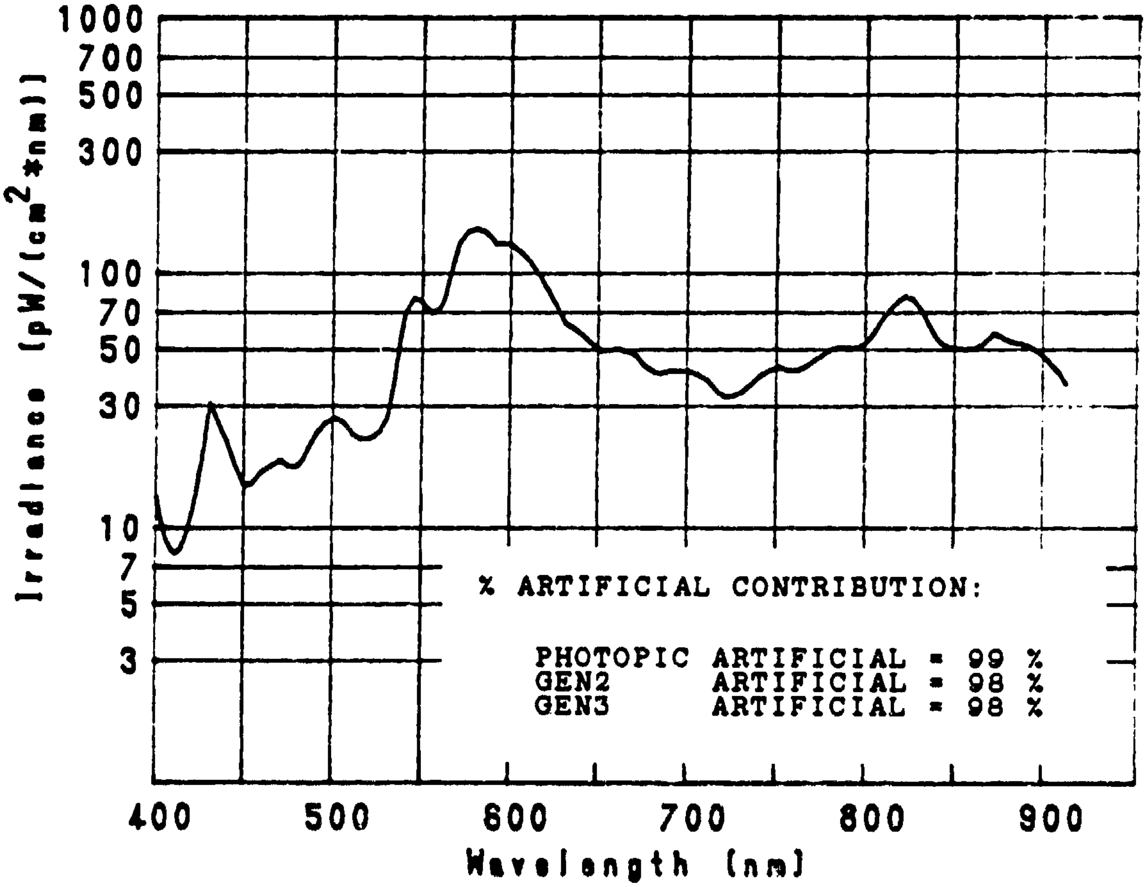
NIGHT SKY RADIOMETRIC DATA

DATE:	10-22-86
TIME:	2305
SITE:	GRISWOLD:BH
CLOUD COVER:	**HORIZON**
CLOUD ALT.(FT):	** MEAS **
MOON INCLINATION(DEG):	12
MOON AZIMUTH(DEG):	70
MOON PHASE:	84%WAN
REF. PANEL AZIMUTH(DEG):	N/A
REF. PANEL INCL.(DEG):	N/A
REL. HUMIDITY (%):	69
TEMPERATURE (F):	52

RADIOMETRIC CALCULATED RESULTS:

PHOTOPIC = 5.28E-3 FC
GEN2 = 3.62E-3 HN2
GEN3 = 3.18E-3 HN3

FILE: FIL009



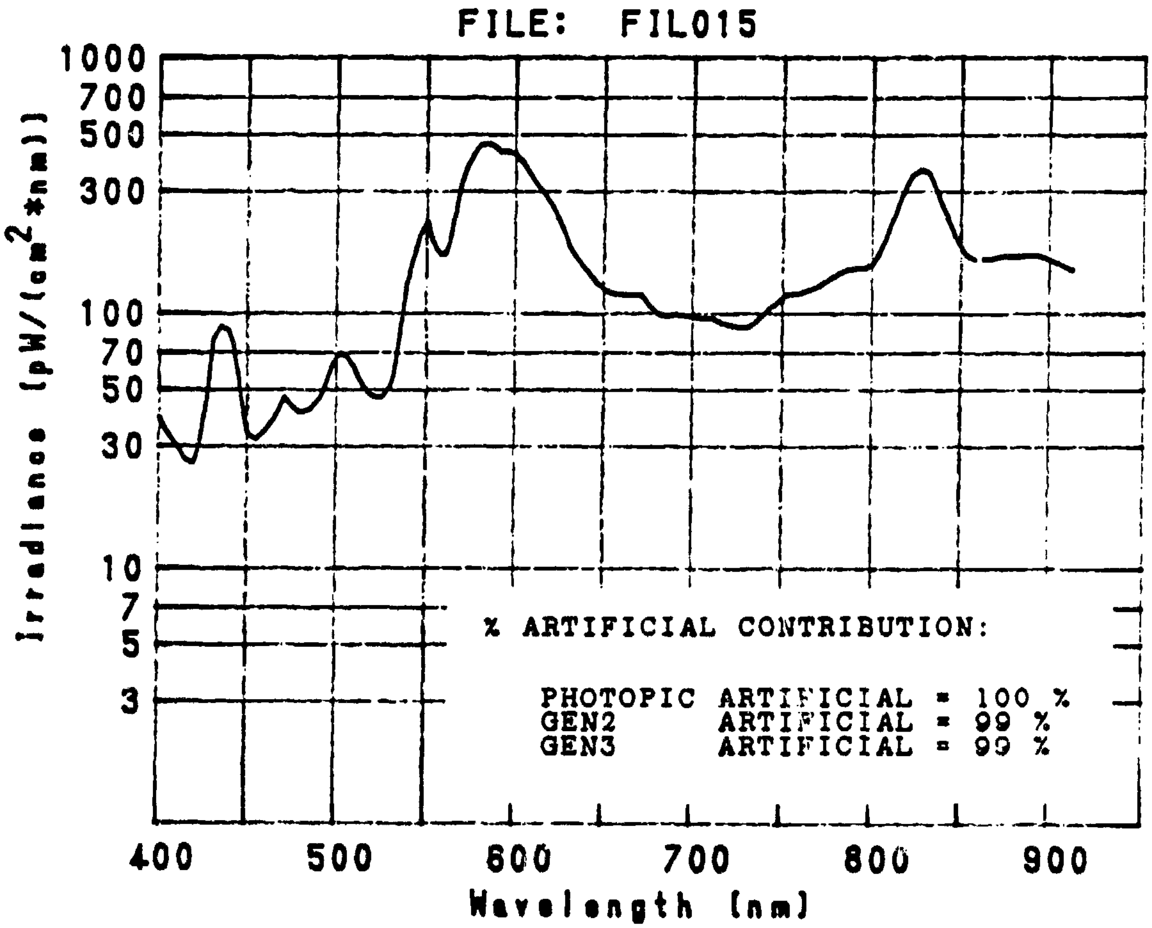
FOE AN/PVS-7(A,B)
FT. BENNING, GA

NIGHT SKY RADIOMETRIC DATA

DATE:	10-23-86
TIME:	2200
SITE:	GRISWOLD:BH
CLOUD COVER:	*UPP.CLOUD*
CLOUD ALT.(FT):	* MEAS. *
MOON INCLINATION(DEG):	N/A
MOON AZIMUTH(DEG):	N/A
MOON PHASE:	N/A
REF. PANEL AZIMUTH(DEG):	N/A
REF. PANEL INCL.(DEG):	N/A
REL. HUMIDITY (%):	69
TEMPERATURE (F):	62

RADIOMETRIC CALCULATED RESULTS:

PHOTOPIC = 1.49E-2 FC
GEN2 = 1.04E-2 HN2
GEN3 = 9.68E-3 HN3



APPENDIX J
LAMP MEASUREMENTS

FOE AN/PVS-7(A,B)
FT. BENNING, GA

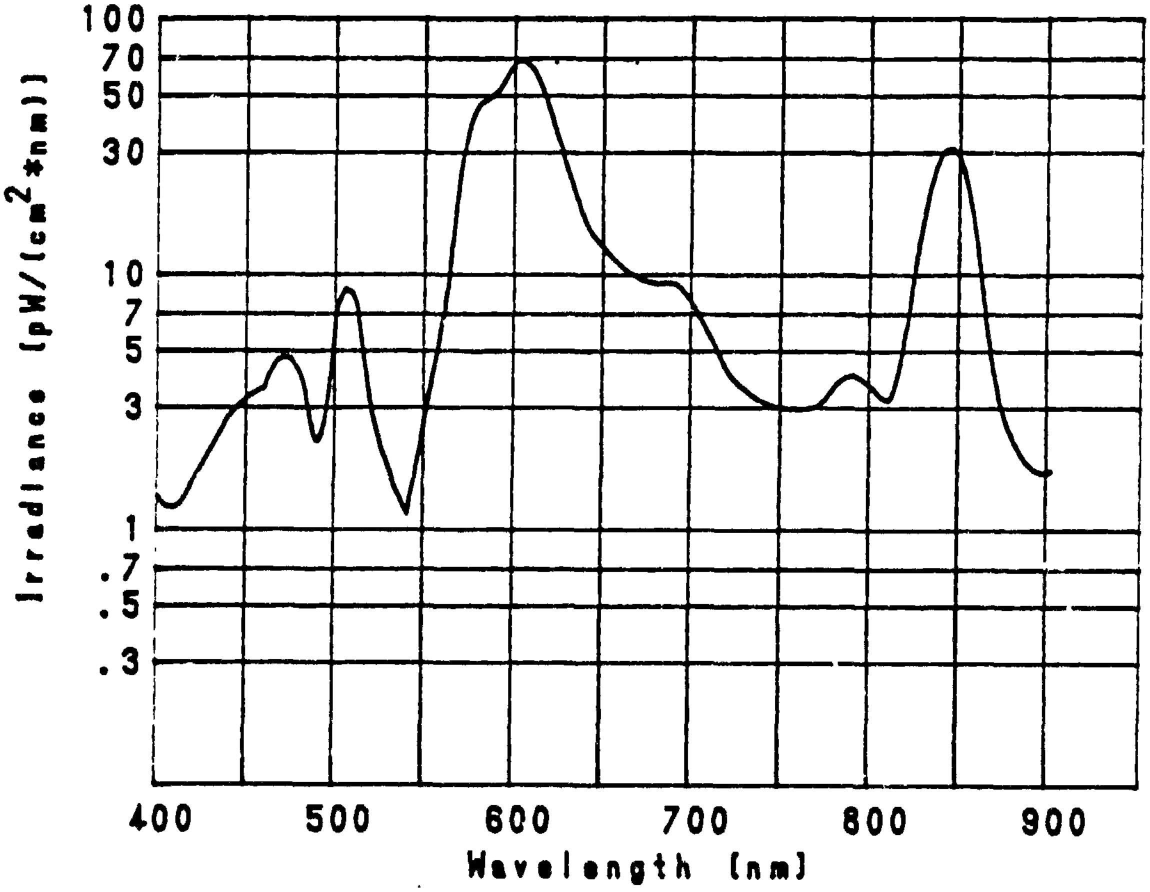
NIGHT SKY RADIOMETRIC DATA

DATE:	11-4-86
TIME:	1855
SITE:	SANDY PATCH
CLOUD COVER:	* HP Na *
CLOUD ALT.(FT):	* LAMP *
MOON INCLINATION(DEG):	N/A
MOON AZIMUTH(DEG):	N/A
MOON PHASE:	N/A
REF. PANEL AZIMUTH(DEG):	N/A
REF. PANEL INCL.(DEG):	N/A
REL. HUMIDITY (%):	N/A
TEMPERATURE (F):	N/A

RADIOMETRIC CALCULATED RESULTS:

PHOTOPIC = 1.45E-3 FC
GEN2 = 8.92E-4 HN2
GEN3 = 7.58E-4 HN3

FILE: FIL031



FOE AN/PVS-7(A,B)
FT. BENNING, GA

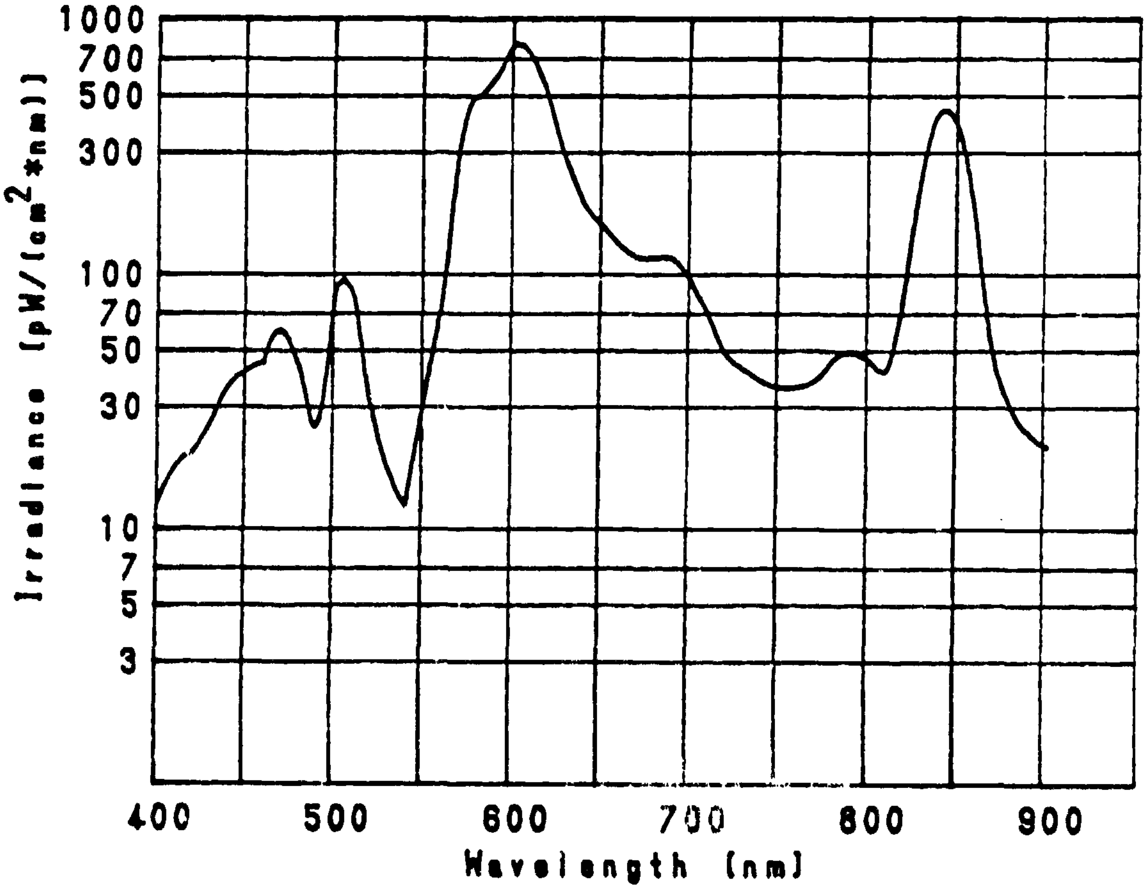
NIGHT SKY RADIOMETRIC DATA

DATE:	11-4-86
TIME:	1915
SITE:	SANDY PATCH
CLOUD COVER:	* HP Na *
CLOUD ALT. (FT):	* LAMP *
MOON INCLINATION(DEG):	N/A
MOON AZIMUTH(DEG):	N/A
MOON PHASE:	N/A
REF. PANEL AZIMUTH(DEG):	N/A
REF. PANEL INCL. (DEG):	N/A
REL. HUMIDITY (%):	N/A
TEMPERATURE (F):	N/A

RADIOMETRIC CALCULATED RESULTS:

PHOTOPIC	=	1.64E-2 FC
GEN2	=	1.05E-2 HN2
GEN3	=	9.32E-3 HN3

FILE: FIL032



FOE AN/PVS-7(A,B)
FT. BENNING, GA

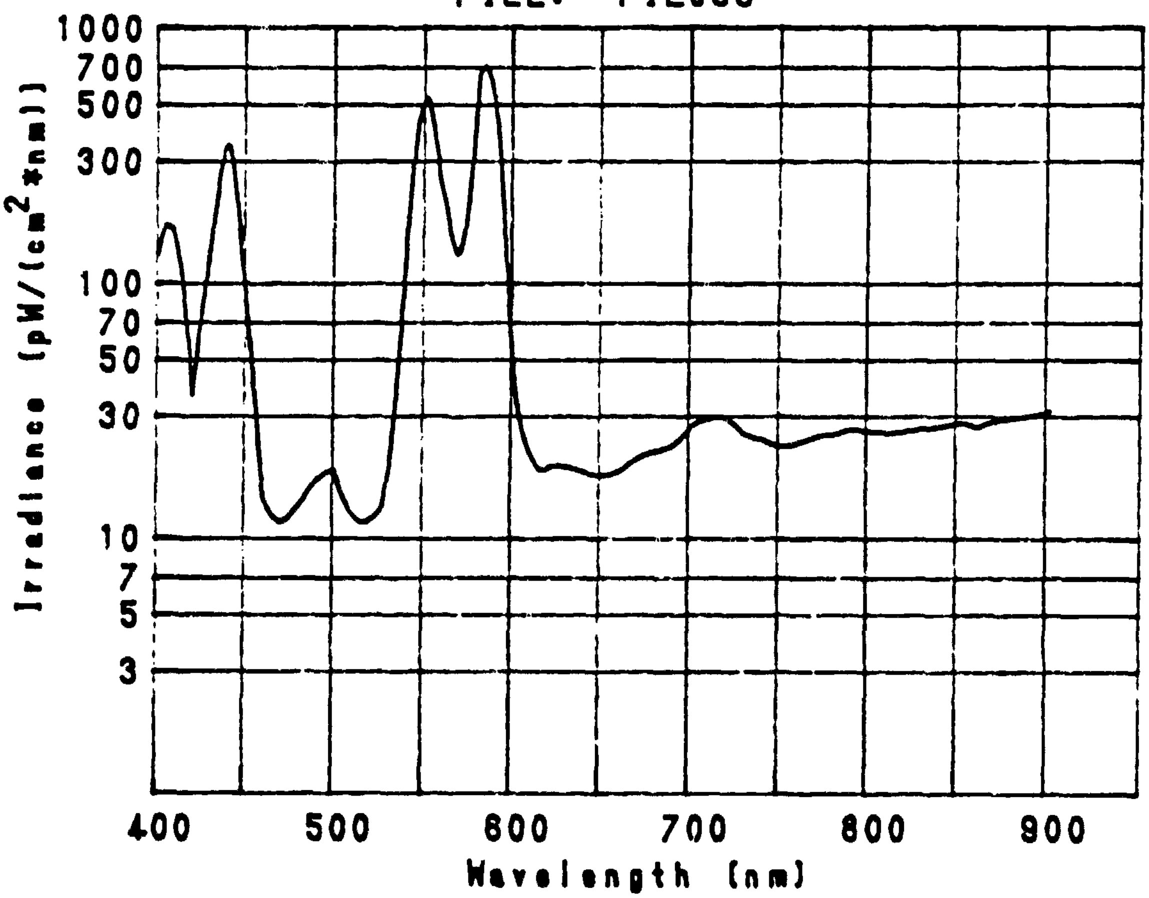
NIGHT SKY RADIOMETRIC DATA

DATE:	11-4-86
TIME:	1940
SITE:	SANDY PATCH
CLOUD COVER:	* HP Hg *
CLOUD ALT.(FT):	* LAMP *
MOON INCLINATION(DEG):	N/A
MOON AZIMUTH(DEG):	N/A
MOON PHASE:	N/A
REF. PANEL AZIMUTH(DEG):	N/A
REF. PANEL INCL.(DEG):	N/A
REL. HUMIDITY (%):	N/A
TEMPERATURE (F):	N/A

RADIOMETRIC CALCULATED RESULTS:

PHOTOPIC = 1.28E-2 FC
GEN2 = 5.61E-3 HN2
GEN3 = 1.84E-3 HN3

FILE: FIL033



FOE AN/PVS-7(A,B)
FT. BENNING, GA

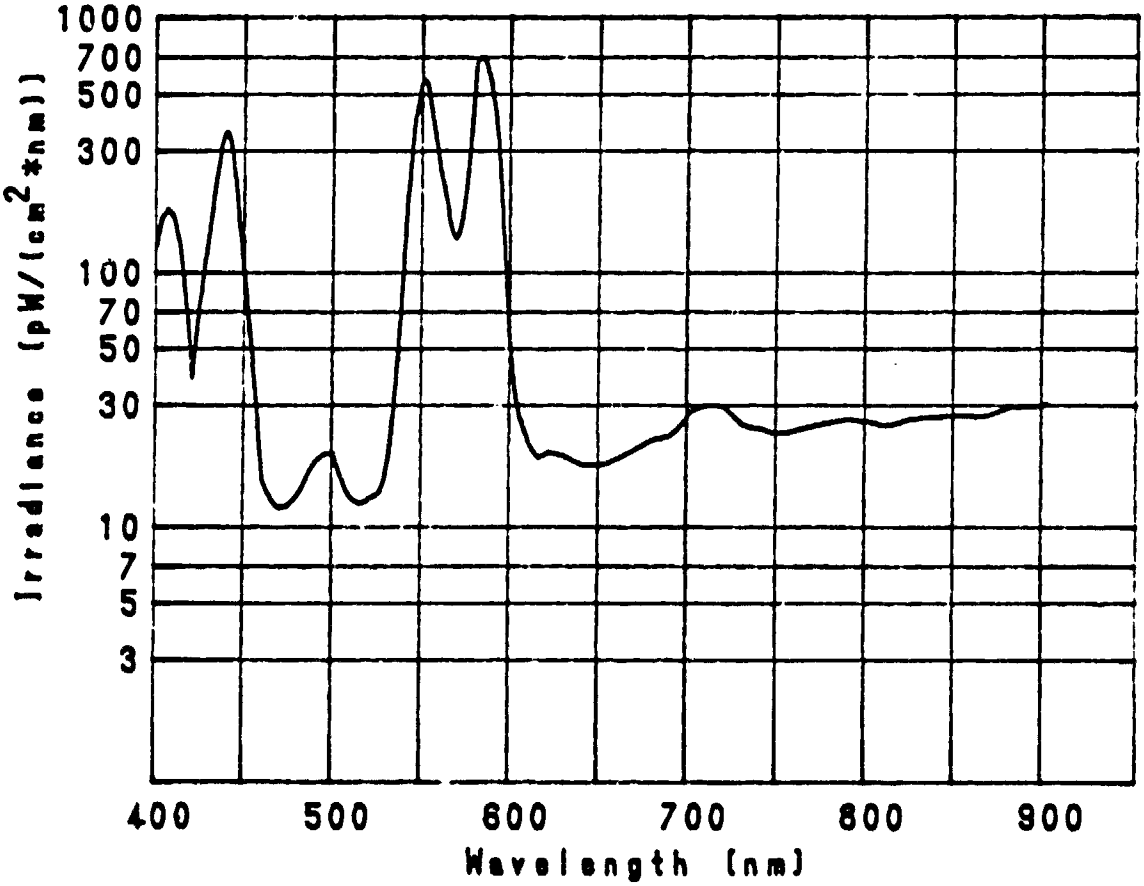
NIGHT SKY RADIOMETRIC DATA

DATE:	11-4-86
TIME:	2000
SITE:	SANDY PATCH
CLOUD COVER:	* HP Hg *
CLOUD ALT.(FT):	* LAMP *
MOON INCLINATION(DEG):	N/A
MOON AZIMUTH(DEG):	N/A
MOON PHASE:	N/A
REF. PANEL AZIMUTH(DEG):	N/A
REF. PANEL INCL.(DEG):	N/A
REL. HUMIDITY (%):	N/A
TEMPERATURE (F):	N/A

RADIOMETRIC CALCULATED RESULTS:

PHOTOPIC = 1.32E-2 FC
GEN2 = 5.76E-3 HN2
GEN3 = 1.83E-3 HN3

FILE: FIL034



FOE AN/PVS-7(A,B)
FT. BENNING, GA

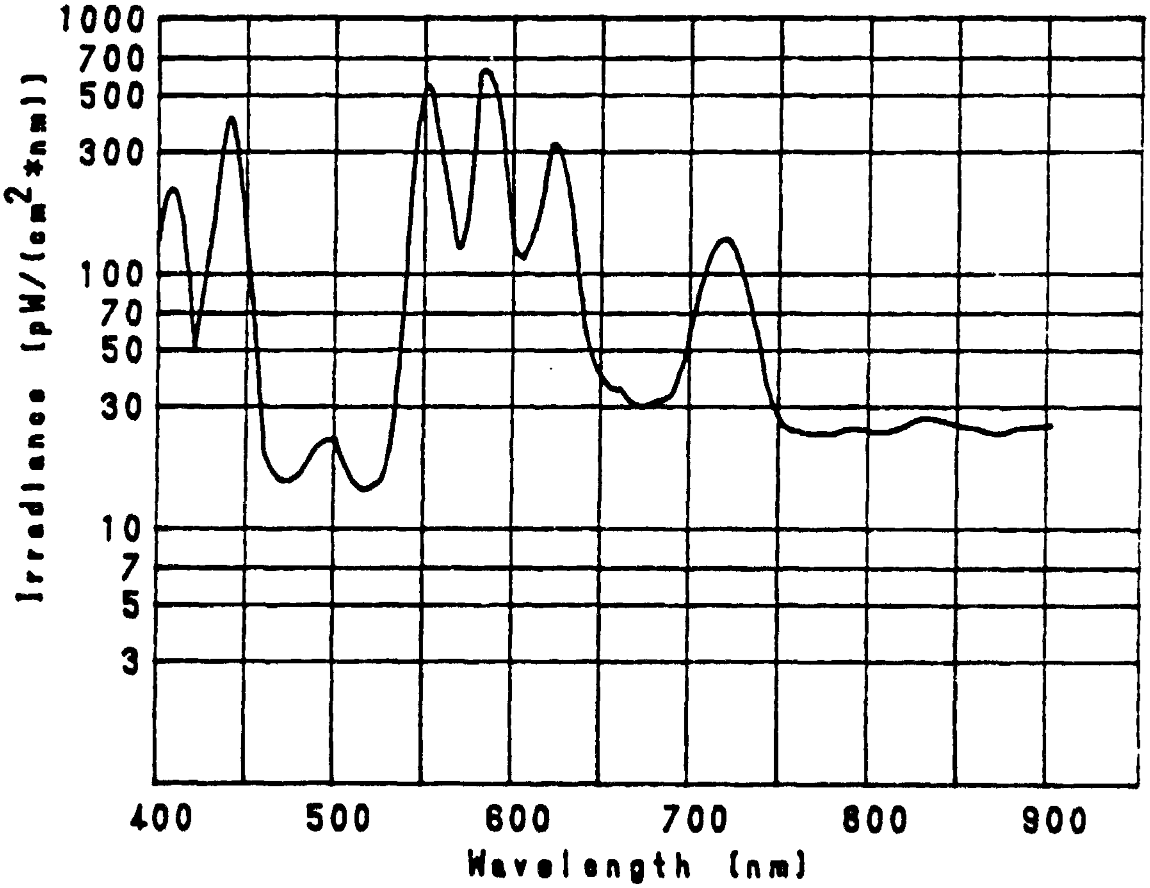
NIGHT SKY RADIOMETRIC DATA

DATE:	11-4-86
TIME:	2030
SITE:	SANDY PATCH
CLOUD COVER:	* HP Hg *
CLOUD ALT. (FT):	* LAMP *
MOON INCLINATION(DEG):	N/A
MOON AZIMUTH(DEG):	N/A
MOON PHASE:	N/A
REF. PANEL AZIMUTH(DEG):	N/A
REF. PANEL INCL. (DEG):	N/A
REL. HUMIDITY (%):	N/A
TEMPERATURE (F):	N/A

RADIOMETRIC CALCULATED RESULTS:

PHOTOPIC = 1.48E-2 FC
GEN2 = 7.72E-3 HN2
GEN3 = 3.89E-3 HN3

FILE: FIL035



APPENDIX K
DATA SUMMARY

FOE NIGHT SKY RADIOMETRIC DATA SUMMARY FORT BENNING, GA

FILE No. (FILnnn)	DATE	TIME (local)	SITE[a]	PANEL AZ. (Deg.)	Light Level: PHOTO-METRIC (FC)	Light Level: GEN2 (HN2)	Light Level: GEN3 (HN3)	Artificial Contribution: PHOTO-METRIC (%)	Artificial Contribution: GEN2 (%)	Artificial Contribution: GEN3 (%)	REMARKS
FIL #C4	10-21-86	2200[b]	GB	350	2.0×10^{-3}	2.0×10^{-3}	2.1×10^{-3}	--	--	--	82% moon
FIL #C5	10-21-86	2300[b]	GB	350	2.9×10^{-3}	2.8×10^{-3}	2.6×10^{-3}	--	--	--	82% moon
FIL006	10-22-86	1940[b]	GB	350	7.7×10^{-4}	6.2×10^{-4}	6.1×10^{-4}	90	88	88	SCT clouds
FIL008	10-22-86	2220[b]	GB	N/A	5.4×10^{-3}	3.6×10^{-3}	3.0×10^{-3}	99	98	98	Horizon meas.
FIL009	10-22-86	2305[b]	GB	N/A	5.3×10^{-3}	3.6×10^{-3}	3.2×10^{-3}	99	98	98	Horizon meas.
FIL010	10-23-86	0005[b]	GB	350	1.7×10^{-3}	1.6×10^{-3}	1.5×10^{-3}	--	--	--	84% moon
FIL011	10-23-86	0035[b]	GB	315	7.5×10^{-4}	6.7×10^{-4}	5.7×10^{-4}	--	--	--	84% moon
FIL013	10-23-86	2030[b]	GB	262	1.2×10^{-3}	8.6×10^{-4}	7.8×10^{-4}	94	91	91	OVC @ 7K ft
FIL014	10-23-86	2130[b]	GB	262	1.2×10^{-3}	8.4×10^{-4}	8.0×10^{-4}	94	91	91	OVC @ 7K ft
FIL015	10-23-86	2200[b]	GB	N/A	1.5×10^{-2}	1.0×10^{-2}	9.7×10^{-3}	100	99	99	Cloud meas.
FIL016	10-27-86	1821	S	330	3.6×10^{-3}	3.0×10^{-3}	2.8×10^{-3}	98	98	97	Traffic & St. lights
FIL017	10-27-86	1927	S	330	2.1×10^{-3}	2.4×10^{-3}	2.7×10^{-3}	97	97	97	Traffic & St. lights
FIL018	10-27-86	2025	S	330	2.5×10^{-3}	1.8×10^{-3}	1.5×10^{-3}	97	96	95	Traffic & St. lights
FIL020	10-28-86	1914	ST	327	1.4×10^{-3}	9.4×10^{-4}	7.0×10^{-4}	95	92	89	Clear starlight
FIL021	10-28-86	2010	ST	327	1.3×10^{-3}	8.9×10^{-4}	6.8×10^{-4}	94	92	89	Clear starlight

Notes: a. G = Griswold Range/Detection area; GB = Griswold Block House; S = Simpson between road and berm; ST = Simpson target area; LF = Lae Field; SP = Sandy Patch

b. EDT

FOE NIGHT SKY RADIOMETRIC DATA SUMMARY FORT BENNING, GA

FILE No. (FILnnn)	DATE	TIME (local)	SITE[a]	PANEL AZ. (Deg.)	Light Level: PHOTO-METRIC (FC)	Light Level: GEN2 (HN2)	Light Level: GEN3 (HN3)	Artificial Contribution: PHOTO-METRIC (%)	Artificial Contribution: GEN2 (%)	Artificial Contribution: GEN3 (%)	REMARKS
FIL022	10-30-86	1857	GB	180	2.0×10^{-4}	1.9×10^{-4}	2.0×10^{-4}	63	61	63	Clear starlight
FIL023	10-30-86	2005	GB	350	3.6×10^{-4}	2.9×10^{-4}	2.8×10^{-4}	80	74	74	High haze over city
FIL024	11-03-86	1840	G	50	4.6×10^{-4}	3.4×10^{-4}	3.0×10^{-4}	84	78	76	Clouds over city only
FIL025	11-03-86	1940	G	50	4.9×10^{-4}	3.7×10^{-4}	3.5×10^{-4}	85	80	79	Clouds over city only
FIL026	11-03-86	2010	G	50	4.7×10^{-4}	3.3×10^{-4}	3.0×10^{-4}	84	78	75	Clouds over city only
FIL027	11-03-86	2145	G	150	1.9×10^{-4}	1.6×10^{-4}	1.6×10^{-4}	62	54	53	Clouds over city only
FIL028	11-03-86	2230	G	150	2.1×10^{-4}	1.7×10^{-4}	1.6×10^{-4}	65	58	55	Clouds over city only
FIL031	11-04-86	1855	SP	N/A	1.5×10^{-3}	8.9×10^{-4}	7.6×10^{-4}	--	--	--	Na lamp meas.
FIL032	11-04-86	1915	SP	N/A	1.6×10^{-2}	1.1×10^{-2}	9.3×10^{-3}	--	--	--	Na lamp meas.
FIL033	11-04-86	1940	SP	N/A	1.3×10^{-2}	5.6×10^{-3}	1.8×10^{-3}	--	--	--	Hg lamp meas.
FIL034	11-04-86	2000	SP	N/A	1.3×10^{-2}	5.8×10^{-3}	1.8×10^{-3}	--	--	--	Hg lamp meas.
FIL035	11-04-86	2030	SP	N/A	1.5×10^{-2}	7.7×10^{-3}	3.9×10^{-3}	--	--	--	Hg lamp meas.
FIL036	11-10-86	1900	LF	0	3.1×10^{-3}	2.6×10^{-3}	2.2×10^{-3}	--	--	--	67% moon
FIL037	11-10-86	2015	LF	0	3.5×10^{-3}	3.1×10^{-3}	2.8×10^{-3}	--	--	--	OVC, 67% moon
FIL040	11-11-86	2030	LF	160	5.8×10^{-3}	4.9×10^{-3}	4.0×10^{-3}	--	--	--	OVC, 76% moon

Notes: a. G = Griswold Range/Detection area; GB = Griswold Block House; S = Simpson between road and berm; ST = Simpson target area; LF = Lae Field; SP = Sandy Patch

b. EDT

FOE NIGHT SKY RADIOMETRIC DATA SUMMARY FORT BENNING, GA

FILE No. (FILnnn)	DATE	TIME (local)	SITE[a]	PANEL AZ. (Deg.)	Light Level PHOTO-METRIC (FC)	GEN2 (HN2)	GEN3 (HN3)	Artificial Contribution PHOTO-METRIC (%)	GEN2 (%)	GEN3 (%)	REMARKS
FIL041	11-11-86	2100	LF	160	9.3×10^{-3}	8.9×10^{-3}	8.0×10^{-3}	--	--	--	76% moon
FIL043	11-12-86	1934	LF	0	2.1×10^{-3}	1.9×10^{-3}	1.6×10^{-3}	--	--	--	84% moon
FIL045	11-12-86	2200	LF	180	5.2×10^{-3}	4.8×10^{-3}	4.1×10^{-3}	--	--	--	OVC, 84% moon
FIL051	12-02-86	1912	GB	345	2.5×10^{-4}	1.9×10^{-4}	1.8×10^{-4}	70	61	58	OVC
FIL052	12-02-86	2010	GB	345	4.5×10^{-4}	3.3×10^{-4}	3.1×10^{-4}	83	78	76	OVC
FIL053	12-02-86	2050	GB	200	1.5×10^{-4}	1.1×10^{-4}	1.0×10^{-4}	49	34	27	Clearing
FIL054	12-02-86	2125	GB	345	1.3×10^{-4}	1.3×10^{-4}	1.0×10^{-4}	43	41	28	Clear
FIL055	12-03-86	1900	GB	250	1.7×10^{-4}	1.6×10^{-4}	1.1×10^{-4}	57	54	35	4% moon
FIL056	12-03-86	1950	GB	350	2.5×10^{-4}	1.8×10^{-4}	1.4×10^{-4}	70	60	47	Clear
FIL057	12-03-86	2040	GB	170	1.3×10^{-4}	1.4×10^{-4}	8.6×10^{-5}	41	46	14	Clear

Notes: a. G = Griswold Range/Detection area; GB = Griswold Block House; S = Simpson between road and berm; ST = Simpson target area; LF = Lae Field; SP = Sandy Patch

b. EDT

APPPENDIX L
RAW DATA VALUES

WAVELENGTH [nm]	FIL#C4 SPECTRAL IRRAD. [pW/(cm^2 nm)]	WAVELENGTH [nm]	FIL#C5 SPECTRAL IRRAD. [pW/(cm^2 nm)]
400	9.23	400	17.02
	8.79		22.37
	10.67		22.16
	12.04		24.74
	16.96		28.13
450	15.61	450	30.21
	17.68		32.11
	19.54		34.14
	18.33		32.76
	20.49		35.62
500	22.88	500	37.79
	22.64		36.20
	22.61		37.04
	24.36		39.37
	28.00		41.88
550	30.39	550	44.76
	30.71		44.40
	31.79		48.50
	34.02		47.27
	33.67		47.85
600	33.43	600	48.66
	34.18		47.19
	33.78		46.19
	32.78		44.16
	32.37		44.55
650	33.04	650	44.39
	34.08		46.24
	34.53		46.21
	34.13		44.74
	33.22		44.66
700	34.36	700	45.27
	33.97		45.66
	33.10		44.63
	34.92		46.30
	36.74		48.10
750	36.61	750	46.27
	33.19		43.23
	35.90		45.11
	42.33		49.09
	42.26		48.76
800	40.45	800	46.90
	38.68		44.30
	37.40		43.75
	37.51		44.26
	39.54		44.38
850	40.56	850	45.44
	42.53		45.46
	43.18		46.61
	43.26		46.15
	44.27		45.33
900	41.02	900	40.24
	35.81		34.75
	39.41		16.51

WAVELENGTH [nm]	FIL006 SPECTRAL IRRAD. [pW/(cm^2 nm)]	WAVELENGTH [nm]	FIL008 SPECTRAL IRRAD. [pW/(cm^2 nm)]
400	3.80	400	14.56
	3.63		7.44
	4.68		11.41
	7.73		33.22
	5.76		20.22
450	3.41	450	12.34
	3.84		15.25
	3.93		15.46
	2.68		15.25
	4.35		20.90
500	4.25	500	25.84
	3.55		21.34
	3.00		20.63
	4.14		26.56
	10.31		74.50
550	10.95	550	77.71
	11.61		75.13
	17.45		136.16
	19.88		155.96
	18.97		131.68
600	21.93	600	129.00
	15.19		109.81
	11.58		87.20
	8.82		63.38
	7.07		57.24
650	6.54	650	46.63
	5.97		45.69
	6.16		42.83
	6.14		36.26
	6.14		36.27
700	6.34	700	35.82
	6.26		34.08
	6.15		29.19
	7.13		29.98
	7.82		36.20
750	7.81	750	39.43
	8.18		38.40
	9.47		41.64
	12.48		45.89
	12.08		47.37
800	13.33	800	51.13
	17.53		65.80
	20.64		77.13
	17.85		65.94
	13.72		50.18
850	13.16	850	47.43
	12.90		49.59
	13.57		51.74
	14.70		52.28
	15.77		54.47
900	14.39	900	43.57
	12.77		35.08

WAVELENGTH [nm]	FIL009 SPECTRAL IRRAD. [pW/(cm^2 nm)]	WAVELENGTH [nm]	FIL010 SPECTRAL IRRAD. [pW/(cm^2 nm)]
400	13.04	400	9.73
	7.92		10.82
	11.42		12.00
	31.01		13.71
	21.16		15.24
450	14.56	450	17.26
	16.59		17.49
	18.38		16.70
	17.64		16.61
	23.29		18.09
500	26.87	500	20.66
	23.25		21.27
	22.42		21.19
	27.78		21.45
	69.64		25.01
550	74.19	550	27.39
	74.28		26.41
	130.31		27.97
	148.21		28.80
	127.88		27.91
600	125.65	600	28.37
	107.72		27.43
	84.35		26.89
	63.02		26.54
	56.10		26.05
650	49.06	650	26.04
	50.03		26.99
	46.96		26.45
	40.45		25.17
	40.99		25.47
700	40.56	700	25.94
	37.54		25.81
	32.45		25.21
	34.22		25.88
	39.69		26.96
750	42.58	750	25.99
	41.09		23.61
	45.41		25.02
	50.09		28.05
	50.38		28.51
800	54.51	800	27.74
	69.37		25.77
	80.44		25.72
	69.21		25.99
	52.80		27.43
850	49.99	850	28.16
	50.72		28.87
	57.71		29.04
	52.87		28.60
	50.94		27.11
900	44.96	900	25.74
	36.59		21.19

WAVELENGTH [nm]	FIL011 SPECTRAL IRRAD. [pW/(cm^2 nm)]	WAVELENGTH [nm]	FIL013 SPECTRAL IRRAD. [pW/(cm^2 nm)]
400	7.81	400	6.53
	8.22		4.87
	8.28		2.85
	9.67		9.52
	10.20		8.53
450	10.39	450	4.00
	10.11		2.89
	8.62		4.84
	7.82		1.92
	9.59		4.80
500	9.63	500	6.44
	10.63		5.37
	8.93		4.41
	9.44		4.99
	10.96		14.32
550	11.91	550	22.37
	12.00		15.65
	12.55		28.20
	13.29		38.79
	12.75		32.14
600	12.55	600	29.07
	10.96		22.23
	10.17		18.93
	9.06		13.61
	9.05		10.78
650	8.47	650	9.40
	8.60		9.00
	8.94		9.17
	8.16		8.07
	8.67		9.24
700	7.98	700	8.65
	8.39		8.39
	8.71		7.82
	9.10		7.56
	9.81		8.87
750	9.54	750	9.69
	8.94		9.83
	10.05		10.67
	11.38		12.94
	11.36		13.98
800	10.97	800	14.78
	10.27		19.97
	10.18		25.00
	10.08		24.65
	11.12		17.74
850	11.31	850	14.31
	11.79		14.07
	12.50		14.80
	12.33		16.66
	12.53		16.17
900	11.07	900	15.35
	8.25		13.63

WAVELENGTH [nm]	FIL014 SPECTRAL IRRAD. [pW/(cm^2 nm)]	WAVELENGTH [nm]	FIL015 SPECTRAL IRRAD. [pW/(cm^2 nm)]
400	4.23	400	38.61
	3.26		29.95
	2.43		26.70
	8.56		77.70
	8.03		80.84
450	1.76	450	33.67
	3.78		34.89
	2.68		46.44
	2.25		40.80
	3.54		46.45
500	5.63	500	68.41
	4.50		58.67
	4.64		46.63
	3.99		54.03
	13.52		141.94
550	20.48	550	229.36
	14.11		170.18
	26.74		338.21
	36.59		453.08
	31.95		425.68
600	28.48	600	408.46
	23.17		320.44
	19.20		254.59
	13.34		176.07
	10.73		141.66
650	9.65	650	121.89
	9.39		117.40
	8.74		116.49
	7.97		97.74
	8.24		97.93
700	8.26	700	94.96
	8.16		94.45
	7.60		88.19
	7.92		88.08
	9.59		101.56
750	10.63	750	117.28
	10.35		120.64
	11.61		129.11
	13.03		143.42
	13.66		149.22
800	15.02	800	161.28
	19.87		237.67
	27.06		345.68
	26.68		346.28
	19.39		234.88
850	15.58	850	168.62
	15.20		161.19
	15.78		166.38
	16.54		165.62
	15.85		166.86
900	16.55	900	157.86
	10.05		146.83

WAVELENGTH [nm]	FIL016 SPECTRAL IRRAD. [pW/(cm^2 nm)]	WAVELENGTH [nm]	FIL017 SPECTRAL IRRAD. [pW/(cm^2 nm)]
400	33.82	400	15.93
	23.94		6.23
	30.19		10.42
	50.60		33.26
	28.54		14.67
450	21.02	450	8.78
	20.76		11.22
	36.93		9.85
	17.80		13.06
	19.98		7.84
500	20.11	500	14.36
	17.74		7.07
	20.83		6.62
	42.58		11.34
	55.91		41.39
550	40.74	550	41.31
	42.57		22.09
	92.11		51.24
	84.30		57.54
	55.01		53.64
600	72.97	600	50.15
	87.72		24.94
	77.37		28.35
	27.32		21.74
	30.47		14.36
650	67.59	650	18.07
	60.75		13.90
	23.43		13.78
	23.70		49.71
	24.13		98.90
700	22.65	700	167.92
	22.21		94.80
	20.01		31.35
	22.21		48.11
	44.19		52.00
750	60.96	750	15.12
	85.71		16.91
	97.73		25.91
	73.28		27.18
	49.99		19.56
800	32.47	800	25.81
	27.97		172.03
	34.54		59.31
	87.99		28.98
	106.45		30.50
850	34.33	850	63.03
	24.39		19.62
	24.85		19.37
	28.77		22.29
	29.27		27.32
900	31.67	900	39.46

WAVELENGTH [nm]	FIL018 SPECTRAL IRRAD. [pW/(cm^2 nm)]	WAVELENGTH [nm]	FIL020 SPECTRAL IRRAD. [pW/(cm^2 nm)]
400	15.37	400	9.86
	6.73		15.03
	8.52		9.10
	30.54		11.15
	13.30		26.85
450	5.46	450	11.38
	5.92		7.43
	6.20		8.28
	5.55		8.24
	10.35		7.70
500	15.41	500	9.58
	21.54		10.72
	26.62		9.38
	20.80		6.94
	48.56		10.78
550	45.46	550	28.87
	38.10		24.37
	70.08		23.32
	56.61		36.82
	31.29		37.34
600	25.84	600	30.39
	25.29		24.07
	27.93		20.63
	57.91		17.44
	16.39		12.10
650	15.04	650	10.39
	13.12		9.71
	14.01		9.33
	26.21		8.13
	14.54		8.21
700	13.13	700	8.29
	12.65		8.56
	17.58		7.86
	39.53		7.26
	35.32		7.97
750	40.95	750	8.93
	23.06		9.82
	35.60		9.03
	53.97		9.49
	37.40		11.65
800	20.03	800	12.08
	25.45		12.13
	22.06		12.31
	24.90		13.19
	24.07		13.70
850	19.51	850	12.79
	18.11		12.41
	21.73		12.67
	21.18		14.44
	22.03		15.62
900	23.92	900	15.94
			16.61

WAVELENGTH [nm]	FIL021 SPECTRAL IRRAD. [pW/(cm^2 nm)]	WAVELENGTH [nm]	FIL022 SPECTRAL IRRAD. [pW/(cm^2 nm)]
400	9.93	400	2.21
	16.48		1.50
	6.79		2.38
	10.82		1.78
	27.32		2.23
450	12.03	450	1.24
	6.23		1.63
	6.92		1.76
	7.10		1.14
	5.58		1.49
500	8.57	500	1.46
	8.60		2.46
	7.54		1.30
	5.95		1.17
	9.54		1.71
550	27.93	550	3.20
	23.77		3.52
	22.30		3.34
	34.56		4.27
	34.98		5.32
600	29.11	600	4.69
	21.74		3.14
	19.52		3.10
	15.04		3.71
	11.50		2.47
650	9.83	650	2.23
	9.52		1.63
	8.87		2.00
	8.33		1.87
	8.36		1.95
700	8.66	700	1.93
	7.98		1.99
	7.62		2.00
	7.65		2.05
	8.98		2.95
750	9.27	750	3.25
	9.18		3.11
	8.59		2.88
	9.73		3.28
	11.61		4.85
800	12.43	800	5.90
	12.97		5.56
	12.10		4.50
	11.94		3.88
	12.93		4.85
850	12.89	850	5.69
	12.88		6.06
	13.14		5.33
	14.07		5.57
	14.61		7.08
900	16.51	900	9.59
	16.23		

WAVELENGTH [nm]	FIL023 SPECTRAL IRRAD. [pW/(cm^2 nm)]
400	2.34
	2.57
	1.93
	3.77
	3.66
450	1.75
	1.92
	1.71
	1.89
	2.32
500	2.13
	1.80
	1.72
	1.99
	3.74
550	6.08
	6.36
	7.15
	9.30
	9.60
600	8.43
	6.23
	5.94
	5.01
	3.96
650	3.20
	3.07
	2.77
	3.07
	3.12
700	2.96
	3.08
	2.83
	3.17
	3.53
750	4.24
	4.18
	3.84
	4.62
	6.09
800	7.15
	6.84
	5.94
	5.41
	6.35
850	7.50
	7.23
	6.61
	7.31
	9.01
900	10.89

WAVELENGTH [nm]	FIL024 SPECTRAL IRRAD. [pW/(cm^2 nm)]
400	3.65
	2.46
	1.75
	4.85
	6.57
450	1.23
	2.96
	2.57
	2.16
	3.67
500	2.96
	2.63
	2.79
	2.74
	4.63
550	8.14
	6.32
	8.89
	12.10
	12.04
600	10.32
	8.35
	7.15
	5.67
	4.90
650	3.99
	3.42
	3.94
	3.63
	3.84
700	3.51
	3.23
	3.18
	3.20
	3.46
750	4.17
	4.33
	4.18
	5.19
	5.96
800	6.81
	6.46
	6.05
	6.19
	6.96
850	7.10
	6.75
	6.56
	6.75
	8.17
900	9.20

WAVELENGTH [nm]	FIL025 SPECTRAL IRRAD. [pW/(cm^2 nm)]	WAVELENGTH [nm]	FIL026 SPECTRAL IRRAD. [pW/(cm^2 nm)]
400	6.11	400	2.07
	3.49		1.89
	1.38		2.05
	4.12		2.77
	4.40		3.54
450	1.16	450	2.29
	1.70		2.23
	2.10		2.82
	2.58		2.38
	2.00		1.91
500	2.27	500	3.25
	2.63		2.05
	3.24		2.59
	2.72		2.16
	5.08		4.38
550	8.13	550	8.03
	6.94		6.43
	10.16		9.52
	13.87		13.74
	12.97		13.01
600	11.36	600	11.22
	8.91		9.12
	7.98		7.88
	6.38		4.72
	5.39		3.36
650	4.24	650	2.99
	4.08		3.00
	3.96		2.47
	4.22		2.93
	4.35		4.06
700	4.13	700	3.17
	4.00		3.65
	3.74		3.68
	3.96		3.92
	4.25		3.71
750	4.49	750	4.46
	5.06		3.71
	5.07		3.84
	5.49		5.02
	6.99		6.03
800	7.49	800	6.48
	7.40		6.42
	6.98		6.29
	7.85		6.78
	8.40		7.13
850	8.09	850	7.36
	7.55		7.10
	7.67		6.13
	8.22		6.80
	8.39		8.46
900	9.82	900	8.57

WAVELENGTH [nm]	FIL027 SPECTRAL IRRAD. [pW/(cm^2 nm)]	WAVELENGTH [nm]	FIL028 SPECTRAL IRRAD. [pW/(cm^2 nm)]
400	1.07	400	2.85
	2.48		1.24
	1.45		0.55
	1.54		1.58
	2.22		2.43
450	1.66	450	2.66
	2.23		1.39
	0.73		1.80
	0.45		1.36
	1.27		1.31
500	1.98	500	1.22
	1.63		2.91
	1.25		1.35
	1.24		1.08
	1.50		1.35
550	3.09	550	3.87
	2.92		3.56
	3.48		3.37
	4.58		5.02
	5.16		5.21
600	4.55	600	4.84
	3.76		4.02
	3.20		2.87
	2.66		3.25
	1.82		2.13
650	2.10	650	2.46
	1.60		2.00
	1.22		2.16
	1.83		1.67
	1.63		1.37
700	1.83	700	2.00
	1.58		1.90
	1.61		1.99
	1.73		1.92
	2.04		1.80
750	1.88	750	2.08
	2.74		2.37
	2.65		2.37
	2.39		2.25
	3.56		2.69
800	3.95	800	3.81
	3.78		4.03
	3.74		3.84
	3.51		3.28
	3.56		4.11
850	4.05	850	4.53
	4.37		4.40
	3.94		3.85
	3.91		3.63
	4.63		4.72
900	5.45	900	5.47

WAVELENGTH [nm]	FIL031 SPECTRAL IRRAD. [pW/(cm^2 nm)]	WAVELENGTH [nm]	FIL032 SPECTRAL IRRAD. [pW/(cm^2 nm)]
400	1.33	400	12.69
	1.22		17.51
	1.58		19.95
	2.08		26.02
	2.78		36.05
450	3.28	450	41.54
	3.57		44.64
	4.72		59.80
	3.98		42.75
	2.23		25.47
500	7.41	500	87.60
	7.94		81.66
	2.89		31.58
	1.67		17.16
	1.15		12.31
550	2.84	550	31.41
	7.32		79.78
	27.34		320.83
	46.38		494.35
	52.77		595.95
600	68.04	600	796.12
	61.14		696.69
	39.09		458.82
	24.06		272.50
	15.39		182.52
650	12.29	650	152.36
	10.57		128.70
	9.43		115.09
	9.14		115.22
	9.07		113.43
700	7.38	700	91.42
	5.53		66.42
	4.00		47.66
	3.43		41.83
	3.12		37.42
750	2.98	750	35.71
	2.95		35.88
	3.08		38.20
	3.72		46.37
	4.01		49.16
800	3.57	800	45.36
	3.30		42.69
	7.04		99.60
	19.31		288.70
	30.65		437.15
850	25.67	850	344.50
	10.18		135.05
	3.42		46.15
	2.15		28.91
	1.71		23.34
900	1.70	900	21.06

WAVELENGTH [nm]	FIL033 SPECTRAL IRRAD. [pW/(cm^2 nm)]	WAVELENGTH [nm]	FIL034 SPECTRAL IRRAD. [pW/(cm^2 nm)]
400	128.92	400	126.46
	151.02		158.37
	36.31		38.27
	138.26		147.00
	342.25		351.94
450	87.72	450	92.66
	14.58		15.35
	11.52		11.88
	13.35		13.36
	16.95		18.12
500	18.51	500	19.32
	12.36		12.93
	11.78		12.85
	17.68		17.99
	139.78		140.20
550	520.66	550	560.68
	233.82		243.62
	133.20		140.12
	648.98		658.76
	431.05		419.22
600	42.91	600	44.01
	20.68		20.87
	18.94		19.59
	19.04		18.80
	18.02		17.47
650	17.54	650	17.54
	18.28		18.50
	20.41		20.21
	21.73		22.11
	23.05		23.04
700	27.34	700	28.08
	29.42		30.00
	29.35		29.22
	25.39		25.10
	24.35		24.30
750	22.85	750	23.23
	23.61		23.99
	24.96		24.93
	25.52		25.79
	26.42		26.31
800	26.22	800	25.78
	25.75		24.91
	26.31		26.11
	26.88		26.89
	27.43		27.06
850	28.17	850	27.33
	27.00		27.04
	28.81		27.85
	29.28		29.60
	30.14		29.61
900	31.34	900	30.42

WAVELENGTH [nm]	FIL035 SPECTRAL IRRAD. [pW/(cm^2 nm)]	WAVELENGTH [nm]	FIL036 SPECTRAL IRRAD. [pW/(cm^2 nm)]
400	134.71	400	18.79
	199.11		25.68
	49.26		21.76
	140.56		24.88
	404.07		34.68
450	121.52	450	31.55
	19.95		30.16
	15.27		31.80
	16.47		29.75
	20.99		29.91
500	22.22	500	33.94
	15.11		35.65
	14.47		32.68
	20.39		31.82
	132.98		34.31
550	533.36	550	50.49
	262.98		49.58
	127.54		46.73
	606.10		62.91
	462.85		67.13
600	121.63	600	62.68
	141.67		58.87
	318.90		52.40
	215.50		46.40
	57.85		39.68
650	38.16	650	35.71
	35.05		33.90
	30.03		37.40
	31.51		36.53
	34.84		37.43
700	66.18	700	35.40
	118.65		32.88
	134.56		32.72
	85.24		31.53
	40.43		29.74
750	25.74	750	29.58
	23.89		33.00
	23.52		34.84
	23.62		33.57
	24.55		34.94
800	23.91	800	39.65
	24.04		39.70
	25.68		39.66
	27.08		41.29
	26.35		41.39
850	25.16	850	42.27
	24.49		39.31
	23.49		39.27
	24.63		42.06
	24.89		42.85
900	25.30	900	43.49

WAVELENGTH [nm]	FIL037 SPECTRAL IRRAD. [pW/(cm^2 nm)]	WAVELENGTH [nm]	FIL040 SPECTRAL IRRAD. [pW/(cm^2 nm)]
400	17.41	400	32.69
	24.48		43.14
	23.63		49.45
	25.56		51.33
	34.54		52.87
450	32.77	450	60.43
	31.96		65.71
	35.15		67.36
	32.58		68.47
	32.91		62.07
500	38.44	500	68.10
	39.61		71.34
	38.13		69.88
	37.61		70.65
	41.09		73.28
550	56.20	550	78.25
	55.60		86.58
	52.35		107.99
	67.74		117.38
	72.62		102.55
600	67.62	600	98.16
	67.00		93.65
	60.92		88.13
	53.91		85.84
	47.16		84.90
650	43.65	650	81.39
	42.34		77.36
	45.59		77.48
	44.90		76.43
	45.94		75.36
700	44.80	700	78.35
	42.76		74.89
	42.00		70.13
	40.04		65.69
	37.24		61.37
750	38.39	750	55.33
	41.84		55.03
	44.35		61.09
	43.33		63.10
	45.43		59.21
800	51.32	800	59.30
	51.00		63.81
	50.41		63.95
	53.16		60.36
	53.47		55.70
850	51.99	850	51.82
	50.20		52.19
	49.56		56.29
	54.97		60.49
	56.37		62.23
900	55.13	900	64.44

WAVELENGTH [nm]	FIL041 SPECTRAL IRRAD. [pW/(cm^2 nm)]	WAVELENGTH [nm]	FIL043 SPECTRAL IRRAD. [pW/(cm^2 nm)]
400	56.59	400	20.29
	72.40		23.43
	85.67		27.11
	83.44		26.00
	89.12		26.58
450	107.59	450	31.78
	138.26		32.95
	153.37		32.25
	149.01		32.24
	122.97		28.37
500	133.01	500	28.19
	111.65		29.30
	133.95		29.38
	123.09		27.23
	115.44		27.96
550	157.98	550	30.38
	159.83		33.06
	150.29		31.67
	147.53		30.47
	148.08		33.92
600	143.02	600	33.13
	132.74		32.63
	131.87		31.56
	126.41		31.63
	105.97		28.77
650	111.16	650	29.15
	100.51		26.81
	94.51		25.58
	105.65		24.87
	115.43		26.84
700	149.58	700	27.02
	151.93		26.00
	131.99		23.75
	158.20		24.06
	152.12		24.53
750	147.99	750	23.73
	134.39		24.27
	154.88		28.03
	156.91		29.38
	146.19		28.54
800	163.98	800	27.56
	176.21		29.72
	181.79		34.36
	159.33		32.12
	149.00		29.22
850	123.58	850	26.37
	132.33		24.65
	144.71		28.37
	140.26		29.05
	151.23		29.17
900	146.39	900	29.36

WAVELENGTH [nm]	FIL045 SPECTRAL IRRAD. [pW/(cm^2 nm)]	WAVELENGTH [nm]	FIL051 SPECTRAL IRRAD. [pW/(cm^2 nm)]
400	29.29	400	3.15
	45.87		1.39
	52.41		0.69
	54.00		2.79
	56.79		1.16
450	63.14	450	0.72
	79.77		4.97
	73.19		1.36
	75.37		0.77
	68.38		0.94
500	71.04	500	0.53
	76.66		0.69
	77.19		1.01
	73.83		1.18
	76.89		3.15
550	77.79	550	3.90
	83.47		6.52
	78.62		5.76
	77.11		7.50
	81.73		4.29
600	76.09	600	5.81
	75.47		4.61
	74.09		4.16
	70.87		2.87
	67.64		2.04
650	65.20	650	2.28
	63.65		2.30
	65.29		2.20
	68.07		2.28
	70.42		2.40
700	73.64	700	2.53
	73.04		1.99
	69.95		2.19
	67.83		2.13
	67.07		2.38
750	63.26	750	2.04
	63.63		2.34
	70.78		2.74
	74.67		2.55
	72.61		3.06
800	72.37	800	3.50
	78.90		3.75
	81.13		4.19
	77.59		4.45
	71.51		5.36
850	67.46	850	6.06
	66.81		4.41
	72.11		4.02
	76.50		4.25
	79.81		
900	80.36		

WAVELENGTH [nm]	FIL052 SPECTRAL IRRAD. [pW/(cm^2 nm)]	WAVELENGTH [nm]	FIL053 SPECTRAL IRRAD. [pW/(cm^2 nm)]
400	2.58	400	4.36
	1.95		1.03
	1.86		0.81
	3.87		1.54
	2.01		1.50
450	0.68	450	0.95
	1.65		0.89
	2.31		0.57
	1.20		0.75
	1.66		0.59
500	2.28	500	1.13
	1.76		1.22
	1.21		1.08
	2.50		1.32
	4.71		1.71
550	5.02	550	2.57
	8.95		2.50
	10.10		3.59
	13.43		2.88
	11.54		2.62
600	11.37	600	2.66
	9.35		2.50
	7.52		2.05
	5.54		1.69
	4.37		1.40
650	3.94	650	1.33
	3.50		1.30
	4.10		1.10
	4.03		1.08
	4.19		1.16
700	3.78	700	1.01
	3.88		1.27
	3.69		1.13
	3.74		1.13
	3.05		1.24
750	3.63	750	1.69
	3.91		1.70
	4.40		1.64
	4.82		1.54
	5.03		1.61
800	5.66	800	2.59
	6.07		3.06
	6.49		2.37
	7.87		2.07
	9.84		2.19
850	9.30	850	2.65
	7.56		2.93
	6.37		2.84
	6.21		2.54

WAVELENGTH [nm]	FIL054 SPECTRAL IRRAD. [pW/(cm^2 nm)]	WAVELENGTH [nm]	FIL055 SPECTRAL IRRAD. [pW/(cm^2 nm)]
400	2.09	400	5.68
	1.27		1.71
	1.04		0.89
	10.50		18.91
	1.64		2.51
450	1.19	450	1.30
	1.66		2.65
	1.03		0.92
	0.91		1.09
	1.03		1.27
500	1.23	500	1.51
	0.75		1.49
	0.86		1.64
	0.76		1.40
	1.48		1.78
550	2.08	550	2.76
	1.85		3.29
	2.12		2.88
	2.98		3.67
	3.15		4.27
600	3.14	600	3.55
	2.74		2.83
	2.29		2.46
	2.16		1.73
	1.97		1.75
650	1.99	650	1.58
	2.01		1.40
	1.36		1.90
	1.40		1.93
	1.50		1.65
700	1.20	700	1.44
	0.99		1.45
	1.17		1.45
	1.17		1.39
	1.74		2.57
750	1.42	750	1.62
	1.46		2.10
	1.15		1.67
	1.49		1.60
	1.90		1.64
800	2.10	800	2.15
	2.26		2.48
	1.89		2.62
	1.68		2.31
	2.05		2.15
850	2.51	850	2.38
	2.33		2.82
	2.46		2.82
	3.00		2.67

WAVELENGTH [nm]	FIL056 SPECTRAL IRRAD. [pW/(cm^2 nm)]	WAVELENGTH [nm]	FIL057 SPECTRAL IRRAD. [pW/(cm^2 nm)]
400	5.22	400	2.14
	2.20		1.22
	1.22		0.87
	6.47		25.03
	3.29		1.65
450	1.76	450	1.00
	2.33		1.48
	1.91		1.53
	1.28		0.60
	1.81		1.13
500	2.49	500	1.91
	1.63		1.13
	1.51		1.15
	0.69		1.74
	2.36		1.45
550	4.58	550	2.08
	6.62		1.73
	4.56		2.43
	5.98		2.55
	6.14		1.91
600	4.78	600	2.40
	3.69		1.68
	3.35		1.99
	2.39		1.45
	2.13		1.36
650	1.99	650	1.52
	2.53		1.95
	2.30		1.50
	2.14		1.08
	1.89		1.08
700	1.88	700	2.05
	1.75		1.01
	1.76		1.28
	1.68		1.06
	3.48		1.52
750	1.79	750	1.28
	2.07		1.19
	1.83		1.10
	3.97		2.70
	1.90		1.11
800	2.38	800	1.67
	1.85		1.62
	2.65		1.87
	2.17		1.43
	2.45		1.27
850	3.95	850	1.77
	2.84		2.49
	3.04		2.23
	2.66		2.73

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